

June 12, 2017

**UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION**

BEFORE THE SECRETARY

In the Matter of)	
)	
Tennessee Valley Authority)	Docket No. 52-047-ESP
)	
(Clinch River Nuclear Site))	
_____)	

PETITION TO INTERVENE AND REQUEST FOR HEARING

I. INTRODUCTION

Pursuant to 10 C.F.R. § 2.309 and the hearing notice published by the Nuclear Regulatory Commission (“NRC” or “Commission”) at 82 Fed. Reg. 16,436 (Apr. 4, 2017), Petitioners Southern Alliance for Clean Energy (“SACE”) and Tennessee Environmental Council (“TEC”) hereby request a hearing and petition to intervene in this proceeding regarding Tennessee Valley Authority’s (“TVA’s”) application for an Early Site Permit (“ESP”) that would allow TVA to bank the Clinch River Nuclear Site as a potential site for construction and operation of a small modular reactor (“SMR”).

Petitioners’ standing to intervene is described in Section II below. In Section III, Petitioners set forth their contentions. In summary, the contentions assert as follows:

- Contention 1 challenges TVA’s application for an exemption from NRC’s emergency planning requirements with respect to the establishment of a ten-mile emergency planning zone (“EPZ”). As demonstrated in the contention, TVA has failed to justify its proposal to reduce the size of the EPZ to the site boundary, or in the alternative a two-

mile radius. Contention 1 is supported by the expert declaration of Dr. Edwin S. Lyman, Senior Staff Scientist with the Union of Concerned Scientists (Attachment 1).

- Contention 2 challenges TVA's failure to address the environmental impacts of accidents involving ignition of spent fuel in the spent fuel storage pool(s) at the proposed SMR. There is no question that the consequences of such accidents could be catastrophic, but TVA has failed to show or even assert that the likelihood of such an accident is remote and speculative. Therefore, the Environmental Report violates NEPA by failing to address the environmental impacts of a spent fuel storage pool fire.
- Contention 3 asserts that the Environmental Report is biased and unfair, because it advocates the technical advantages of SMRs as an energy alternative, even though TVA formally elected not to address energy alternatives or the need for power in the Environmental Report for the ESP. Contention 3 is supported by the expert declaration of Dr. M.V. Ramana, Professor and the Simons Chair in Disarmament, Global and Human Security at the Liu Institute for Global Issues, University of British Columbia, Vancouver, Canada (Attachment 2).

II. DESCRIPTION OF PETITIONERS AND THEIR STANDING TO INTERVENE

A. Description of Petitioners

Petitioners are civic and environmental groups located in the area of the Clinch River Nuclear Site. SACE is a nonprofit, nonpartisan membership organization that promotes responsible energy choices that solve global warming problems and ensure clean, safe and healthy communities throughout the Southeast. SACE has staff and members throughout the Southeast, including offices in Knoxville, Tennessee; Asheville, North Carolina; and Atlanta and Savannah, Georgia.

TEC is a nonprofit organization that seeks to educate and advocate for the conservation and improvement of Tennessee's environment, public health and communities. TEC works to protect and conserve Tennessee's communities, public health, and the natural resources on which they depend. TEC currently has about 1,000 members.

B. Standing to Intervene

Pursuant to 10 C.F.R. § 2.309(f), a request for a hearing must address: (1) the nature of the petitioner's right under the Atomic Energy Act ("AEA") to be made a party to the proceeding, (2) the nature and extent of the petitioner's property, financial, or other interest in the proceeding, and (3) the possible effect of any order that may be entered in the proceeding on the petitioner's interest. The Atomic Safety and Licensing Board ("ASLB") summarized these standing requirements as follows:

In determining whether a petitioner has sufficient interest to intervene in a proceeding, the Commission has traditionally applied judicial concepts of standing. Contemporaneous judicial standards for standing require a petitioner to demonstrate that (1) it has suffered or will suffer a distinct and palpable harm that constitutes injury-in-fact within the zone of interest arguably protected by the governing statutes (*e.g.*, the Atomic Energy Act of 1954 and the National Environmental Policy Act of 1969); (2) the injury can fairly be traced to the challenged actions; and (3) the injury is likely to be redressed by a favorable decision. An organization that wishes to intervene in a proceeding may do so either in its own right by demonstrating harm to its organizational interests, or in a representational capacity by demonstrating harm to its members. To intervene in a representational capacity, an organization must show not only that at least one of its members would fulfill the standing requirements, but also that he or she has authorized the organization to represent his or her interests.

Pacific Gas & Electric Co. (Diablo Canyon Power Plant Independent Spent Fuel Storage Installation), LBP-02-23, 56 NRC 413, 426 (2002).

Petitioners' standing to participate in this proceeding is demonstrated by the declarations of the following members of the Petitioner organizations, who have authorized Petitioners to represent their interests in this proceeding.

Louis Gorenflo, SACE member (Attachment 3)
Jennifer Stachowski, SACE member (Attachment 4)
Ralph Hutchison, SACE member (Attachment 5)
Daniel Stephenson, SACE and TEC member (Attachment 6)
Ralph Hutchison, TEC member (Attachment 7)
Adam Hughes, TEC member (Attachment 8)
James Fall, Chief Financial Officer in SACE Knoxville office (Attachment 9)
Stephen A. Smith, SACE member and Executive Director (Attachment 10)

The attached declarations demonstrate that Petitioners' members live near the site of Clinch River site, *i.e.*, within 50 miles, and would be adversely affected by an accident at the proposed SMR. SACE's Knoxville office is also located within 50 miles of the site, and therefore SACE's employees would be adversely affected by an accident at the proposed SMR. As discussed in Contention 2 below, a fire in a spent fuel pool could displace as many as 4 million people out to 500 miles. In addition, Petitioners have presumptive standing by virtue of their location within 50 miles of a nuclear plant that may be operated on the site. *Diablo Canyon*, 56 NRC at 426-27 (citing *Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 and 4), LBP-01-06, 53 NRC 138, 146, *aff'd*, CLI-01-17, 54 NRC 3 (2001)).

By intervening in this proceeding, Petitioners seek to protect their members' and SACE's employees' health, safety and lives, as well as the health and safety of the general public and the environment by opposing the issuance of an ESP to TVA for the Clinch River site. Petitioners seek to ensure that no ESP is issued by the NRC unless TVA demonstrates full compliance with federal laws for protection of public health and safety and the environment.

III. CONTENTIONS

Contention 1: Inadequate Emergency Plan

1. Statement of the Contention: The Emergency Plan in the ESP application for the Clinch River SMR is inadequate to satisfy 10 C.F.R. §52.17(b)(2) because the size of the proposed plume exposure Emergency Planning Zone (“EPZ”) is less than the minimum ten-mile radius required by 10 C.F.R. §50.47(c)(2) for most nuclear power reactors. While TVA claims to qualify for an exemption from 10 C.F.R. §50.47(c)(2) “due to the decreased potential consequences associated with such a facility” (ESP Application, Part 6 at 1), TVA has not demonstrated that it satisfies the NRC Staff’s criterion for such an exemption with respect to the potential for a spent fuel storage pool fire. As provided in an NRC guidance document that has been consistently applied to exemption applications, the Staff will not approve an exemption to offsite emergency planning requirements unless the applicant can demonstrate that the time between uncovering of spent fuel and initiation of a zirconium fire in the spent fuel storage pool is ten hours or more. Preliminary Draft, Regulatory Improvements for Power Reactors Transitioning to Decommissioning at A-1 (RIN # 3150-AJ59, NRC Docket # NRC-2015-0070, 2015) (“Draft Guidance for Decommissioning Reactors”) (NRC ADAMS Accession No. ML16309A332).¹

Therefore, for consistency with this principle, in order for TVA to qualify for an exemption from the ten-mile EPZ, TVA should have to demonstrate for the spent fuel storage pool(s) to be located at the proposed site that in the event of a loss of cooling and adiabatic

¹ In reliance on the Draft Guidance for Decommissioning Reactors, the NRC has issued exemptions from emergency planning requirements for numerous reactors, including Kewaunee, Crystal River, San Onofre, and Vermont Yankee. *See* Memorandum from Stephen S. Koenick to William M. Dean re: Transition to Decommissioning Lessons Learned Report (Oct. 28, 2016) (ADAMS Accession No. ML16176A339).

heating conditions (*i.e.*, conditions in which a range of factors may prevent heat from leaving individual fuel assemblies or spent fuel racks), at least ten hours would elapse before a zirconium fire would be initiated. Such an analysis would depend on fuel design features, as well as operational factors that are not specified in the ESP application. If this information is not available or not sufficiently well-defined to enable a technically sound analysis that could plausibly demonstrate the condition is met with adequate margin, TVA's exemption request should be rejected without prejudice and TVA should be advised to re-submit it at the COL stage.

2. Brief Summary of Basis for the Contention: While detailed emergency plans are not required for ESP applications, NRC regulation 10 C.F.R. § 52.17(b)(2) provides ESP applicants with the option to submit emergency plans for approval by the NRC. As part of its ESP, TVA has submitted two alternative emergency plans – one with an EPZ that conforms to the site boundary (Part 5A of the ESP application) and the other with a two-mile EPZ (Part B of the ESP application). Part 6 of TVA's ESP application consists of a request for an exemption from the ten-mile EPZ requirement in 10 C.F.R. §§ 50.33(g), 50.47(b), and 50.47(c)(2).

As demonstrated in Draft Guidance for Decommissioning Reactors, the NRC considers pool fires to constitute contributors to the accident risk that must be protected against through the emergency planning process. *Id.* at A-1. In Part 6, entitled "Exemptions and Departures," TVA asserts that an EPZ extending beyond the site boundary (or, alternatively, a two-mile radius) is not necessary to achieve the purpose of NRC's emergency planning regulations because "there are no offsite consequences from any credible event in excess of the [U.S. Environmental Protection Agency Protective Action Guidelines]." *Id.*, Table 1-1. But TVA completely fails to

discuss any SMR design features that would decrease the potential for spent fuel pool fires to result in significant off-site radiological releases.

The Draft Guidance for Decommissioning Reactors advocates the allowance of relaxation of the ten-mile EPZ requirement for decommissioning reactors on the ground that after a reactor has shut down and spent fuel has cooled for a period of years, the time between uncovering of spent fuel and ignition of spent fuel zirconium cladding (assumed to occur when the cladding temperature reaches 900°C) in a spent fuel storage pool increases to at least ten hours. *Id.* This guidance is based in turn on NUREG-1738, Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants (2001) (ADAMS Accession No. ML13251A342). For operating plants, the NRC has demonstrated that cladding temperatures can reach 900°C (1173 K) in less than 10 hours for certain accident scenarios. NUREG-2161, Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor at 132-33 (2014) (ADAMS Accession No. ML13297070) (“Consequence Study”).

In the case of an operating SMR or other type of reactor, recently discharged hot spent fuel is loaded periodically into the spent fuel pool. In the case of multiple modules that share one spent fuel pool, like the NuScale SMR design, this could happen as often as every two months or even more frequently, depending on the number of modules and the fuel management strategy. As a result, the time between uncovering of spent fuel and ignition could be significantly less than ten hours.

It is well established that significant radiological consequences of a pool fire could extend beyond the site boundary, and for that matter well beyond a ten-mile EPZ. Consequence Study at 169 (reporting that 4 million people could be displaced out to 500 miles). In the NRC’s License Renewal Generic Environmental Impact Statement, the NRC also concluded that the

environmental impacts of a pool fire are “comparable to those from the reactor accidents at full power.” NUREG-1437, Generic Environmental Impact Statement for License Renewal of Nuclear Plants at 1-28 (2013). The potential for reactor accidents to have significant adverse public health effects within at least a ten-mile radius -- including early and latent fatalities -- is discussed in NRC’s emergency planning guidance documents. *See* NUREG-0396, Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants (1978) and NUREG-0654/FEMA-REP-1, Rev. 1, Criteria for Protective Action Recommendations for Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants (1980). Thus, before an exemption from the ten-mile EPZ requirement in NRC’s emergency planning regulations may be approved, TVA should be required to demonstrate that the time between uncovering of spent fuel and ignition of spent fuel is comparable to a spent fuel pool at a decommissioning reactor, *i.e.*, greater than ten hours.

The information provided by TVA should be sufficiently detailed to allow the NRC Staff, the parties and the Atomic Safety and Licensing Board (“ASLB”) to independently verify TVA’s representations. It appears doubtful that TVA will be able to supply the NRC with that information, given that (a) TVA has not yet chosen a design for the proposed SMR, (b) only one design (NuScale) has been submitted to the NRC, and (c) even the NuScale design has not been reviewed or approved by the NRC, and is still in the early stages of review. If that is the case, the NRC should reject TVA’s exemption application without prejudice, and allow it to be re-submitted at the COL stage.

3. Demonstration that the Contention is Within the Scope of the Proceeding: This contention is within the scope of this ESP proceeding because it raises an issue of compliance with NRC safety regulations for issuance of an ESP.

4. Demonstration that the Contention is Material to the Findings NRC Must Make to issue an ESP for the proposed TVA SMR: The contention is material to the findings that NRC must make in order to issue an ESP for the proposed TVA SMR because it seeks to ensure that TVA fulfills NRC's emergency planning regulations with respect to the size of the EPZ.

5. Concise Statement of the Facts or Expert Opinion Supporting the Contention, Along With Appropriate Citations to Supporting Scientific or Factual Materials: The facts and expert opinion supporting this contention, and the citations relied on by Petitioners, are stated above. In addition, this contention is supported by the attached Declaration of Dr. Edwin S. Lyman (Attachment 1).

Contention 2: Failure to Address Consequences of Pool Fires

1. Statement of the Contention: The Environmental Report fails to satisfy NEPA because it does not address the consequences of a fire in the spent fuel storage pool, nor does it demonstrate that a pool fire is remote and speculative.

2. Brief Summary of Basis for the Contention: The consequences of spent fuel pool fires must be considered in any environmental analysis of the impacts of reactor operation, because the NRC has not ruled out their likelihood as remote and speculative. *State of New York v. NRC*, 681 F.3d 471, 483 (D.C. Cir. 2012). *See also* NUREG-1437, Generic Environmental Impact Statement for License Renewal of Nuclear Plants at 1-28 (2013) ("License Renewal GEIS") (concluding the environmental impacts of pool fires are "comparable to those from the

reactor accidents at full power.”). TVA claims that the design of the spent fuel storage pool(s) for the proposed SMR has “spent fuel pool cooling without the need for active heat removal.”

Environmental Report at 9.3-2. But the Environmental Report does not state that the cooling system renders pool fires remote and speculative.

As discussed in Contention 1, it is well established that the radiological consequences of a pool fire are potentially catastrophic. For instance, radioactive fallout from a pool fire could displace as many as 4 million people out to 500 miles. Consequence Study at 169. The potential for reactor accidents to have significant adverse public health effects within at least a ten-mile radius -- including early and latent fatalities -- is also discussed in NRC’s emergency planning guidance documents. *See* NUREG-0396, NUREG-0654. In the License Renewal GEIS, the NRC also concluded that the environmental impacts of a pool fire are “comparable to those from the reactor accidents at full power.” *Id.* at 1-28 (2013).

Therefore, in the absence of a documented and supported assertion that the potential for a pool fire is remote and speculative, TVA must address the consequences of a pool fire in its Environmental Report.

3. Demonstration that the Contention is Within the Scope of the Proceeding: This contention is within the scope of this ESP proceeding because it seeks consideration of the consequences of a type of severe accident that NRC views as reasonably foreseeable and therefore must address in the EIS for the proposed ESP.

4. Demonstration that the Contention is Material to the Findings NRC Must Make to issue an ESP for the proposed TVA SMR: The contention is material to the findings that NRC must make in order to issue an ESP for the proposed TVA SMR because it relates to the

question of whether TVA has addressed all reasonably foreseeable impacts of operating an SMR in its Environmental Report, as required by NEPA. *State of New York*, 681 F.3d at 483.

5. Concise Statement of the Facts or Expert Opinion Supporting the Contention, Along With Appropriate Citations to Supporting Scientific or Factual Materials: The facts supporting this contention, and the citations relied on by Petitioners, are stated above.

Contention 3 – Impermissible Discussion of Energy Alternatives and Technical Advantages

1. Statement of Contention: The ESP application violates the National Environmental Policy Act (“NEPA”), 42 U.S.C. § 4321-4370f, and NRC implementing regulations because it contains impermissible language comparing the proposed SMR to other energy alternatives and discussing the economic and technical advantages of the facility. The language is impermissible because TVA has explicitly invoked 10 C.F.R. §51.50(b)(2), which excuses it from discussing the economic, technical, or other benefits of the proposed facility such as need for power. *See* Environmental Report, Chapter 8 (postponing need for power discussion), Environmental Report Section 9.2 (postponing energy alternatives discussion).² By formally choosing to exclude consideration of alternatives from its Environmental Report, TVA has effectively precluded Petitioners from submitting contentions on those subjects.

² *See* Environmental Report at 8-1:

Title 10 of the Code of Federal Regulations 51.50(b)(2) does not require a need for power discussion be included in an early site permit application. The need for power discussion is to be included in the combined license application.

See also Environmental Report, Section 9.2, “Energy Alternatives.” The “Energy Alternatives” section is a blank page because “[t]his section is not required for an Early Site Permit Application.” *Id.* at 9.2-1.

Under the circumstances, TVA must restrict the content of the Environmental Report to the impacts of construction and operation and a limited evaluation of alternatives related solely to the selection of the site. Any language comparing the proposed SMR to other energy alternatives, or purporting to justify the need for the SMR, should be stricken from the Environmental Report.

Furthermore, such language should not be included in the NRC's Environmental Impact Statement ("EIS") for the proposed ESP. Such an EIS would end up becoming an advertisement for SMRs rather than the rigorous, unbiased and independent scientific study required by NEPA. *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 348 (1989); *National Audubon Society v. Dep't of Navy*, 422 F.3d 174, 185 (4th Cir. 2005); 40 C.F.R. §1500.1(b).

In the alternative TVA may elect to address energy alternatives and need for power in the Environmental Report. In that case, fairness requires that Petitioners must be provided a reasonable opportunity to submit contentions on the new alternatives analysis.

2. Brief Summary of Basis for the Contention:

a. Requirements of NEPA

NEPA implements a "broad national commitment to protecting and promoting environmental quality." *Louisiana Energy Services, L.P.* (Claiborne Enrichment Center), CLI-98-3, 47 NRC 77, 87 (1998) (quoting *Robertson*, 490 U.S. at 348 and citing 42 U.S.C. § 4331). NEPA has two key purposes: to ensure that the agency "will have available, and will carefully consider, detailed information concerning significant environmental impacts" before it makes a decision; and to guarantee that "the relevant information will be made available to the larger audience that may also play a role in the decision-making process and implementation of that decision." *Robertson*, 490 U.S. at 349.

In fulfilling NEPA's first purpose of evaluating the environmental impacts of its decisions, requires a federal agency to take a "hard look" at potential environmental consequences by preparing an EIS prior to any "major Federal action[] significantly affecting the quality of the human environment." *Robertson*, 490 U.S. at 349; 42 U.S.C. § 4332(c). The "hallmarks of a 'hard look' are thorough investigation into environmental impacts and forthright acknowledgment of potential environmental harms." *National Audubon Society*, 422 F.3d at 185. In addition, the agency must "rigorously explore and objectively evaluate the projected environmental impacts of all reasonable alternatives for completing the proposed action." *Van Ee v. EPA*, 202 F.3d 296, 309 (D.C. Cir. 2000). In considering alternatives, the agency must examine the "alternative of no action." 40 C.F.R. § 1502.14.

In fulfilling NEPA's second purpose of public participation, the agency's environmental analysis must be published for public comment "to permit the public a role in the agency's decision-making process." *Robertson*, 490 U.S. at 349-50; *Hughes River Watershed Conservancy v. Glickman*, 81 F.3d 437, 443 (4th Cir. 1996). NRC's Part 51 regulations also allow interested members of the public to participate in the environmental decision-making process through the NRC's hearing process. 10 C.F.R. §51.104(a).

b. Regulatory requirements for NEPA compliance in ESP proceedings

Because an ESP approves only the banking of a site and not construction or operation of any nuclear facility, the NRC limits the scope of an EIS to issues related to the siting of the facility. As explained in the preamble to the rule, the NRC intended to focus the environmental analysis for ESP applications on issues related to site suitability, such as environmental impacts of construction and operation and alternative sites:

The environmental report and EIS for an early site permit must address the benefits associated with issuance of the early site permit (e.g., early resolution of siting issues,

early resolution of issues on the environmental impacts of construction and operation of a reactor(s) that fall within the site characteristics, and ability of potential nuclear power plant licensees to “bank” sites on which nuclear power plants could be located without obtaining a full construction permit or combined license). The benefits (and impacts) of issuing an early site permit must always be addressed in the environmental report and EIS for an early site permit, regardless of whether the early site permit applicant chooses to defer consideration of the benefits associated with the construction and operation of a nuclear power plant that may be located at the early site permit site. *This is because the “benefits * * * of the proposed action” for which the discussion may be deferred are the benefits associated with the construction and operation of a nuclear power plant that may be located at the early site permit site; the benefits which may be deferred are entirely separate from the benefits of issuing an early site permit. The proposed action of issuing an early site permit is not the same as the “proposed action” of constructing and operating a nuclear power plant for which the discussion of benefits (including need for power) may be deferred under § 51.50(b).*

Final Rule: Licenses, Certifications, and Approvals for Nuclear Power Plants, 72 Fed. Reg.

49,352, 49,430 (Aug. 28, 2007) (emphasis added). Accordingly, NRC regulation 10 C.F.R.

§51.50(b)(2) provides that an environmental report for an ESP application “need not include an assessment of the economic, technical, or other benefits (for example, need for power) and costs of the proposed action or an evaluation of alternative energy sources.” As explained in the preamble, the choice is up to the applicant:

Environmental reports must focus on the environmental effects of construction and operation of a nuclear reactor, or reactors, which have characteristics that fall within the design parameters postulated in the early site permit. Environmental reports must also include an evaluation of alternative sites to determine whether there is any obviously superior alternative to the site proposed. Environmental reports submitted in an early site permit application *are not required to but may include* an assessment of the economic, technical, and other benefits and costs of the proposed action or an analysis of other energy alternatives.

Id. at 49,434 (emphasis added). Thus, the NRC does not consider the energy alternative issue to be material to the issuance of an ESP, unless the applicant chooses to address the issue.

In a proceeding where the applicant decides not to address energy alternatives at the ESP stage, the NRC prohibits members of the public from raising contentions regarding those issues, because the NRC does not require those issues to be addressed in its ESP licensing decisions.

See, e.g., Dominion Nuclear North Anna, L.L.C. (Early Site Permit for North Anna ESP Site), LBP-04-18, 60 NRC 253, 264 (2004) (citing *Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 and 4), LBP-01-06, 53 NRC 138, 159 (2001); *Pacific Gas & Electric Co.* (Diablo Canyon Nuclear Power Plant, Units 1 and 2), LBP-93-01, 37 NRC 5, 29-30 (2001); *Public Service Co. of New Hampshire* (Seabrook Station, Units 1 and 2), LBP-82-106, 26 NRC 1649, 1656 (1982); *Yankee Atomic Electric Co.* (Yankee Nuclear Power Station), CLI-96-7, 43 NRC 235, 251 (1996); *Arizona Public Service Co.* (Palo Verde Nuclear Generating Station, Units 1, 2, and 3), LBP-91-19, 33 NRC 397, 410, *aff'd in part and rev'd in part on other grounds*, CLI-91-12, 34 NRC 149 (1991) (holding that a contention advocating stricter requirements than agency rules impose or that otherwise seek to litigate a generic NRC determination are inadmissible)). Accordingly, with the exception of the issue of site alternatives, NRC prohibits members of the public from seeking consideration of alternatives in an Environmental Report or EIS for an ESP, including comparisons of the proposed operational technology to other technologies for production of electricity.

In hearings on NEPA issues, the NRC also requires fairness to all parties. *Hydro Resources, Inc.* (P.O. Box 15910, Rio Rancho, NM 87174), CLI-01-04, 53 NRC 31, 38 (2001). As the Commission held in *Hydro Resources, Inc.*, the NRC may not issue a license based on an EIS whose contents it has shielded from challenge in a hearing.

b. Comparison of alternatives in TVA's ESP application

In its ESP application, TVA has chosen *not* to address the issues of energy alternatives or need for the proposed SMR, and has instead postponed those issues to the Combined Operating Licensing ("COL") stage. *See* Environmental Report, Chapter 8 (postponing need for power discussion), Environmental Report Section 9.2 (postponing energy alternatives discussion).

Although the first paragraph of the “Purpose and Need” statement (Section 1.1.1) appropriately defines the purpose and need for issuance of the ESP in the limited manner prescribed by NRC regulations (*i.e.*, “to provide for resolution of site safety and environmental issues, which provides stability in the licensing process”), Chapter 1 of the Environmental Report is brimming with claims that SMR technology is preferable to other energy technology on a host of issues, including safety, security, reliability, carbon reduction, water use, and economies of scale. And in Chapter 9, TVA’s discussion of the “no action” alternative, TVA laments that all of these asserted advantages of SMRs would be lost if TVA did not receive an ESP.

For instance, TVA promotes “SMR technology” as preferable for serving federal facilities:

The SMR technology is designed with inherent enhanced safety and security features. SMR deployment will demonstrate that the technology is capable of incrementally supplying clean, secure, reliable power that is less vulnerable to disruption to facilities owned by federal agencies (e.g., U.S. Department of Energy (DOE), U.S. Department of Defense (DoD), TVA, etc.).

Environmental Report at 1-1. TVA asserts that building an SMR “near federal facilities” could provide “enhanced reliability and other benefits, by providing continued operation during a widespread and extended loss of the electrical power grid, meeting reliability needs with clean energy that supports carbon reduction directives.” *Id.* at 1-2. TVA also compares SMRs favorably to coal, to “assist federal facilities with meeting carbon reduction objectives.” *Id.* at 1-3.

To support its claims regarding the special suitability of SMRs to supply electricity to federal facilities, TVA invokes the imprimatur of DOE:

DOE expressed its support to TVA for the development and licensing of SMRs as a means to meet DOE goals of improving the environmental, economic, and energy security outlook for the United States (Reference 1-5). DOE believes that SMR deployment near federal facilities could provide enhanced reliability and other benefits,

by providing continued operation during a widespread and extended loss of the electrical power grid, meeting reliability needs with clean energy that supports carbon reduction directives. DOE specifically requested TVA to assess, as a part of the deployment project planning and licensing process, the ability of SMRs to continue to supply electricity to nearby offsite customers during a disruption to offsite power supplies. This includes electricity transmission to those customers in a manner less vulnerable to intentional destructive acts and natural phenomena that could disrupt the power supply.

Environmental Report at 1-2.

TVA also asserts that SMRs have certain benefits in relation to light water reactors (“LWRs”):

SMRs provide the benefits of nuclear-generated power in situations where large nuclear units, with an approximate electrical output exceeding 1000 MWe, are not practical, because of transmission system constraints, limited space or water availability, or constraints on the availability of capital for construction and operation.

Environmental Report at 1-1. *See also id.* at 1-4 (“SMRs may provide the benefits of nuclear-generated power in situations where large nuclear units are not practical . . .”).

Further, TVA claims that an SMR would serve national security needs: Power generated by SMRs could be used for addressing critical energy security issues. Their use on or immediately adjacent to DoD or DOE facilities, using robust transmission (e.g., armored transformers, underground transmission), could address national security needs by providing reliable electric power in the event of a major grid disruption. A more reliable electric power supply could be accomplished by the SMR operation in “power island” mode with robust transmission to critical facilities. In addition, intentional destructive acts (e.g., terrorist attacks) and natural phenomena (e.g., tornadoes, floods, etc.) could disrupt the grid and the ability to restore most generation sources.”

Id. at 1-2.

In addition, TVA favorably compares the reliability SMRs to renewable energy sources, asserting that SMRS:

can provide reliable energy for extended operation. Because nuclear reactors require fuel replenishment less frequently than other power generation sources (coal, gas, wind and solar), SMRs are less vulnerable to interruptions of fuel supply and delivery systems. TVA could demonstrate this “power islanding” and secure supply concept as part of the [Clinch River] SMR project by utilizing controls, switching, and transmission capabilities to disconnect the SMR power plant from the electrical grid while maintaining power from the SMR power plant to a specified DOE power need. Such a demonstration

would show that SMR technology is capable of supplying reliable power that is less vulnerable to disruption from intentional destructive acts and natural phenomena.

Id. at 1-2.

Finally, TVA asserts that SMRs are preferable to other reactor designs for their safety features:

SMR design features include underground containment and inherent safe-shutdown features, longer station blackout coping time without external intervention, and core and spent fuel pool cooling without the need for active heat removal. These key features advance safety by eliminating several design basis accident scenarios. Development of a security-informed design efficiently provides the same or better protection against the threats large reactors must consider. Physical security is designed into the SMR plant architecture, incorporating lessons learned from significant shifts in security posture since 2001, and the opportunity to build more inherently secure features into the initial design. In Chapter 7, TVA also compares SMRs favorably to other reactors with respect to accident risks.

In Section 9.1, TVA once again introduces impermissible energy alternative considerations by describing the disadvantages of the “no-action alternative” as the lack of the supposed benefits described above, as well as the failure to create “new jobs” or to realize the “technological and financial benefits to the local, community Tennessee Valley, and the nation that would result from the construction of the first-of-its-kind SMRs.” *Id.* at 9.1-1 – 9.1-2. Similarly, TVA includes the same set of inappropriate energy-related alternatives in its discussion of alternative sites in Section 9.3. *Id.* at 9.3-2 – 9.3-3.

c. TVA’s comparisons of SMRs with other technologies are unlawful

TVA’s claims regarding the favorable comparison of SMRs with other energy alternatives must be stricken from the Environmental Report, and may not be included in the EIS for the ESP, because TVA has waived the right to make them by choosing not to address energy alternatives or the need for power in the Environmental Report. *Id.*, Chapter 8 and page 9-2. In addition, TVA’s claims regarding energy-related alternatives should be stricken in fairness to

Petitioners, because Petitioners are precluded from raising issues related to energy alternatives and need for power by virtue of TVA's decision not to formally address those alternatives.

TVA's claims regarding energy alternatives are not only impermissible, but they are unsupported; some are even nonsensical. Thus, to allow them to remain, unchallenged, would reduce the Environmental Report to an advertisement for SMRs, without support or verification, and without providing the context of a comprehensive environmental analysis. For instance:

- The Environmental Report lacks a thorough comparison of SMRs with other energy technologies. TVA makes selective comparisons of SMRs with other energy technologies, but does not provide a comprehensive comparison. For instance, TVA compares SMRs with coal, gas, wind and solar on the factor of reliability. Environmental Report at 1-2. But it does not make a comprehensive analysis that addresses all relevant factors, such as carbon reduction, water use, air and water impacts, generation of waste products, and costs.
- The Environmental Report fails to acknowledge that solar and wind energy sources can meet all the other objectives listed by TVA (carbon reduction, safety, and incremental deployment), and have less deleterious environmental impacts, in particular water use. In fact, the magnitude of impact on water use is listed in Table 3.1-2 of the Environmental Report, which states that: "The expected (and maximum) rate of removal of water from a natural source to replace water losses from closed cooling water system" are "17,078 gpm (expected) [and] 25,608 gpm (maximum)." Assuming that TVA used a reactor capacity of 800 MW, that expected rate translates to 1,281 gallons/MW/hour. That rate of water withdrawal is higher than almost any other form of electricity generation. A

combined cycle natural gas plant will be about a factor of four lower.³ Solar photovoltaics (PV) and wind use negligible amounts of water; PV plants, for example, use about 1 gallon/MW/hour.

- To the extent that the Environmental Report compares SMRs with other energy sources on the factor of reliability, the comparison makes only partial sense. TVA asserts that: "Because nuclear reactors require fuel replenishment less frequently than other power generation sources (coal, gas, wind and solar), SMRs are less vulnerable to interruptions of fuel supply and delivery systems." While the statement is true for coal and gas, it is irrational in the case of wind and solar because they need no fuel replenishment. Renewable sources of power like solar and wind are, therefore, not vulnerable to fuel disruption. Although these are intermittent in nature, that concern can be addressed in a number of ways, in particular by incorporating on-site energy storage technologies.
- TVA asserts that SMR technology provides "a way to supply federal mission-critical loads with reliable power from generation and transmission that is less vulnerable to supply disruption from intentional destructive acts and natural phenomenon than typical commercial power generation facilities and transmission systems." Environmental Report at 9.3-1. But TVA lumps generation and transmission together, without justification. Reliance on SMR technology has nothing to do with the security of transmission systems. In addition, TVA fails to address the United State's history of unsuccessful experimentation with small reactors, which suggests that SMRs are quite unlikely to be

³ J. Macknick et al., *Operational water consumption and withdrawal factors for electricity generating technologies: a review of existing literature*, 7 ENVIRON. RES. LETT. 45802 (2012).

reliable sources of generating power in the first place.⁴ Prior experience that is particularly important to take note of is the Army's Nuclear Power Program, which was started in the 1950s, and resulted in the construction of eight small reactors. The experiences with these reactors reveal the potential for failure implicit with SMRs. The PM-3A reactor at McMurdo Sound in Antarctica, for example, "developed several malfunctions, including leaks in its primary system [and] cracks in the containment vessel that had to be welded."⁵ The leaks from the plant resulted in significant contamination and nearly 14,000 tons of contaminated soil was physically removed and shipped to Port Hueneme, a naval base north of Los Angeles, for disposal. The Army eventually cancelled the program in 1976, due to poor economics as well as the realization that diesel generators were a superior option for supplying power to remote areas. The official history of the Army's Nuclear Power Program termed the development of small reactors "expensive and time consuming."⁶

- In both Chapter 1 and Chapter 9, the Environmental Report asserts:

SMR technology can assist federal facilities with meeting carbon reduction objectives. Energy-related carbon dioxide (CO₂) emissions account for more than 80 percent of greenhouse gas (GHG) emissions in the United States. Studies show that on average coal combustion generates approximately 894-975 grams of CO₂ per kilowatt-hour (g/kWh) of electricity generated. Natural gas generates an estimated 450-519 g/kWh. Nuclear power emission rates have been calculated to range from 6 - 26 g/kWh.

⁴ M.V. Ramana, *The Forgotten History of Small Nuclear Reactors*, IEEE SPECTRUM, 2015, <http://spectrum.ieee.org/energy/nuclear/the-forgotten-history-of-small-nuclear-reactors> (last visited May 24, 2015); M. V. Ramana, *The checkered operational history of high temperature gas cooled reactors*, 72 BULLETIN OF THE ATOMIC SCIENTISTS 171-79 (2016).

⁵ LAWRENCE H. SUID, *THE ARMY'S NUCLEAR POWER PROGRAM: THE EVOLUTION OF A SUPPORT AGENCY* 111 (1990).

⁶ Suid, *supra*, at 93.

Id. at 1-3, 9.3-2. TVA’s unsupported assertion that nuclear power emission rates have been calculated to range from 6 to 26 grams per kilowatt hour is erroneous in two key respects. First, independent studies suggest that there is much uncertainty about the level of emissions associated with the generation of nuclear energy. A widely cited academic study shows that estimates of lifecycle emissions from nuclear power plants vary by over two orders of magnitude, from 1.4 to 288 g/kWh of CO₂, with a mean value of 66 g/kWh.⁷ Second, and more important, SMRs require more uranium fuel for each kWh of electricity generated.⁸ Because of their smaller size and higher area to volume ratio, SMRs will necessarily leak more neutrons from the core when compared to larger reactors. As a result, SMRs need more fuel for each kWh of electricity generated in comparison to the large LWRs that are most common around the world, and that are the basis for the emission estimates made so far (either the 6-26 g/kWh or the 1.4-288 g/kWh). Emissions of CO₂ associated with uranium mining, processing, and enrichment are the dominant contributions to the lifecycle emissions associated with nuclear power. Therefore, this increased need for fuel would result in a corresponding increase in the CO₂ emissions per kWh.

- TVA claims that its SMR design improves on spent fuel pool safety by providing for “spent fuel pool cooling without the need for active heat removal.” Environmental Report at 1-3, 9.3-2. But this assertion does not mention other relevant information demonstrating that SMRs may require greater spent fuel storage capacity than LWRs,

⁷ Benjamin K. Sovacool, *Valuing the greenhouse gas emissions from nuclear power: A critical survey*, 36 ENERGY POLICY 2950–63 (2008).

⁸ Alexander Glaser, Laura Berzak Hopkins & M.V. Ramana, *Resource Requirements and Proliferation Risks Associated with Small Modular Reactors*, 184 NUCLEAR TECHNOLOGY 121–29 (2013).

because they could generate a larger quantity of spent fuel for each kWh of electricity generated – additional impacts that should be compared with the safety benefits claimed by TVA. *See, e.g.*, Glaser et al., cited in note 8 above. For instance, TVA’s calculations appear to use a burnup value of 51 gigawatt-days per metric ton of uranium (“GWD/tU”). This value is much higher than some of the reported burnups of the designs of the four potential SMRs under consideration by TVA. For example, the International Atomic Energy Agency lists the burnup of the Holtec SMR design as 32 GWD/tU.⁹ At this relatively low burnup, the Holtec SMR will generate more spent fuel than an SMR design that has a burnup of 51 GWD/tU. In turn, this would mean that the fuel pool capacity and, possibly, dry storage capacity, will have to be increased.

This is only a partial list of deficiencies in TVA’s discussion of energy alternatives, provided for purposes of illustrating the bias and lack of rigor in TVA’s discussion, as further grounds for Petitioners’ argument that the discussion should be stricken from the Environmental Report. If and when TVA decides to formally address the issue of energy alternatives in a revised Environmental Report, Petitioners will review it and may submit a contention that challenges its contents with a more comprehensive list of deficiencies.

3. Demonstration that the Contention is Within the Scope of the Proceeding: This contention is within the scope of this ESP proceeding because it seeks compliance with NEPA and NRC regulations for the implementation of NEPA in ESP applications.

4. Demonstration that the Contention is Material to the Findings NRC Must Make to issue an ESP for the proposed TVA SMR: The contention is material to the findings that NRC must make in order to issue an ESP for the proposed TVA SMR because it relates to the

⁹ IAEA, ADVANCES IN SMALL MODULAR REACTOR TECHNOLOGY DEVELOPMENTS 89 (2014).

question of whether TVA's Environmental Report improperly addresses issues that TVA has determined should be excluded from this ESP proceeding and therefore may not be addressed by TVA or NRC and also may not be challenged by Petitioners in contentions.

5. Concise Statement of the Facts or Expert Opinion Supporting the Contention, Along With Appropriate Citations to Supporting Scientific or Factual Materials: The facts and expert opinion supporting this contention, and the citations relied on by Petitioners, are stated above. This contention is supported by the attached declaration of Dr. M.V. Ramana.

IV. CONCLUSION

For the foregoing reasons, Petitioners' contentions should be admitted and Petitioners should be admitted as parties to this proceeding.

Respectfully submitted,

_____/signed electronically by/____

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240-393-9285
dcurran@harmoncurran.com

June 12, 2017

CERTIFICATE OF SERVICE

I certify that on June 12, 2017, I posted copies of the foregoing Petition to Intervene and Request for Hearing, including Attachments 1 through 10, on the NRC's Electronic Information Exchange System.

 /signed electronically by/

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)	
)	
Tennessee Valley Authority)	Docket No. 52-047-ESP
)	
(Clinch River Nuclear Site))	
)	

**DECLARATION OF DR. EDWIN S. LYMAN IN SUPPORT OF
PETITIONERS' CONTENTION 1 (EMERGENCY PLANNING)**

Under penalty of perjury, Edwin S. Lyman declares as follows:

1. My name is Edwin S. Lyman. I am a Senior Scientist at the Union of Concerned Scientists.
2. I am a qualified expert on matters relating to nuclear power plant safety and security. I earned a doctorate in physics from Cornell University in 1992. From 1992 to 1995, I was a postdoctoral research associate at Princeton University's Center for Energy and Environmental Studies (now the Science and Global Security Program), where my research focused on the prevention of nuclear proliferation, nuclear and radiological terrorism, and nuclear accidents. I have published articles and letters regarding those issues in journals and magazines including *Science*, *Nature*, *The Bulletin of the Atomic Scientists*, *Science and Global Security*, *Arms Control Today*, *Nuclear Engineering International*, *New Scientist* and *Energy and Environmental Science*. I am a co-author (with David Lochbaum and Susan Q. Stranahan) of the book *Fukushima: The Story of a Nuclear Disaster* (The New Press, 2014).
3. I have considerable experience and expertise with respect to the issue of spent fuel pool fire risks, and have briefed both the NRC and the National Academy of Sciences on issues related to pool fire risks. In addition, I am a co-author of the article "Nuclear Safety Regulation in the Post-Fukushima Era," which was published in *Science* magazine on May 26th, 2017 and focuses on spent fuel pool fire risks. A copy of my curriculum vitae is attached.
4. I am familiar with the licensing-related filings and correspondence that have been submitted by Tennessee Valley Authority ("TVA") in support of its application for an Early Site Permit for a Small Modular Reactor ("SMR") on the Clinch River Nuclear Site. I am also familiar with applicable regulations, policies, and guidance documents of the U.S. Nuclear Regulatory Commission ("NRC").
5. I assisted Petitioners with the preparation of their Contention 1, which challenges

TVA's request for an exemption from NRC's emergency planning requirements. The factual assertions in the contention are true and correct to the best of my knowledge, and the opinions expressed therein are based on my best professional judgment.

A handwritten signature in black ink, appearing to read "Edwin S. Lyman". The signature is fluid and cursive, with a long horizontal stroke extending to the right.

Edwin S. Lyman, Ph.D.

June 9, 2017

Edwin Stuart Lyman
Curriculum Vitæ

Education

Ph.D, Cornell University, Theoretical Physics, August 1992.

M.S., Cornell University, Physics, January 1990.

A.B., *summa cum laude*, New York University, Physics, June 1986; Phi Beta Kappa.

Professional Experience

May 1, 2003 – Present: Senior Scientist, Union of Concerned Scientists.

Spring 2015: Adjunct Professor, Elliott School of International Affairs, The George Washington University, Washington, DC. Taught Master's level course on nuclear energy.

June 2002 – April 2003: President, Nuclear Control Institute, Washington, D.C.

July 1995 – May 2002: Scientific Director, Nuclear Control Institute, Washington, D.C.

August 1992 – June 1995: Postdoctoral research associate, Center for Energy and Environmental Studies, Princeton University, Princeton, NJ.

Spring 1995: Preceptor for Environmental Studies 302, "Perspectives on Environmental Issues: Values and Policies."

Spring 1994: Lecturer, Woodrow Wilson School. Preceptor for WWS 304, "Science, Technology and Public Policy."

July 1988 – June 1992: Graduate research assistant, Newman Laboratory of Nuclear Studies, Cornell University, Ithaca, NY. Conducted thesis research on high-energy physics under the supervision of Prof. S.H.-H. Tye.

August 1986–June 1988: Andrew D. White Graduate Fellow, Physics, Cornell University.

Other

Active Nuclear Regulatory Commission "L" clearance

Books and Book Chapters

D. Lochbaum, E. Lyman and S.Q. Stranahan, *Fukushima: The Story of a Nuclear Disaster*. The New Press, New York, 2014.

E. Lyman, "Nuclear Energy and Human Health," *Encyclopedia of Environmental Health*, Elsevier Science, 2011.

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T. Clements, E. Lyman and F. von Hippel, "The Future of Plutonium Disposition," *Arms Control Today*, June/July 2013.

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E. Lyman, "Rotblat's Pursuit of Nuclear Peace," *New Scientist*, January 25, 2012.

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E. Lyman, "Security Since September 11th," *Nuclear Engineering International*, May 20, 2010.

E. Lyman, "Thirty Years after TMI: Five Continuing Vulnerabilities," *Bulletin of the Atomic Scientists*, March 23, 2009.

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E. Lyman and F. von Hippel, "Reprocessing Revisited: The International Dimensions of the Global Nuclear Energy Partnership," *Arms Control Today*, April 2008, 6-14.

J. Beyea, E. Lyman and F. von Hippel, "Damages from a Major Release of ^{137}Cs Into the Atmosphere of the United States," *Science and Global Security* **12** (2004) 125-136.

G. Bunn, C. Braun, A. Glaser, E. Lyman and F. Steinhausler, "Research Reactor Vulnerability to Sabotage by Terrorists," *Science and Global Security* **11** (2003) 85-107.

D. Hirsch, D. Lochbaum and E. Lyman, "The NRC's Dirty Little Secret," *Bulletin of the Atomic Scientists* (May/June 2003).

R. Alvarez, J. Beyea, K. Janberg, J. Kang, E. Lyman, A. Macfarlane, G. Thompson and F. von Hippel, "Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States," *Science and Global Security* **11** (2003) 1-51.

E. Lyman, "Revisiting Nuclear Power Plant Safety" (letter), *Science* 299 (2003), 202.

E. Lyman, "The Pebble-Bed Modular Reactor: Safety Issues," *Physics and Society*, American Physical Society, October 2001.

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E. Lyman, "Preventing an American Fukushima," Union of Concerned Scientists, March 2016.

E. Lyman, "Excess Plutonium Disposition: The Failure of MOX and the Promise of Its Alternatives," Union of Concerned Scientists, December 2014.

E. Lyman, "Small Isn't Always Beautiful: Safety, Security and Cost Concerns About Small Modular Reactors," Union of Concerned Scientists, September 2013.

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E. Lyman, "Chernobyl on the Hudson? The Health and Environmental Impacts of a Terrorist Attack at the Indian Point Nuclear Power Plant," commissioned by Riverkeeper, Inc., September 2004.

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E. Lyman, "The Solubility of Plutonium in Glass," PU/CEES Report No. 275, Center for Energy and Environmental Studies, Princeton University, April 1993.

Selected Invited Talks and Testimony

"Perspectives on Security Issues," presentation at NRC Commission closed briefing, June 23, 2016.

Testimony on advanced nuclear reactors before the Senate Committee on Environment and Public Works, Subcommittee on Clean Air and Nuclear Safety, April 21, 2016.

"Alternatives to MOX," presentation to the Savannah River Site Citizens' Advisory Board, Augusta, GA, March 29, 2016 (with Frank von Hippel)

"NRC's Fukushima Response: Lessons Learned and Lessons Unheeded," presentation at the NRC Regulatory Information Conference, March 10, 2016.

"Fixing the NRC's Broken Framework for Reducing Severe Accident Risk," presentation to the NRC Advisory Committee on Reactor Safeguards, December 1, 2015.

"UCS Perspectives on NRC and Industry Actions in Response to Fukushima," presentation at NRC Commission briefing, April 30, 2015.

"Perception versus Reality: UCS Views on Nuclear and Radiological Terrorism Risks," presentation at the Institute of Nuclear Materials Management "Reducing the Risk" Workshop, Washington, DC, March 17, 2015.

"Fukushima and its Lessons for Nuclear Safety," seminar at The Library of Congress, February 19, 2015.

"Production of Mo-99 Without the Use of Highly Enriched Uranium: Perspectives of the Union of Concerned Scientists," presentation to the National Academy of Sciences Committee on Status of Mo-99 Production, February 12, 2015.

"Safety and Security of Spent Fuel Storage in the United States," presentation to the National Academy of Sciences Fukushima Lessons Learned Panel, January 29, 2015.

"UCS Views on the NRC's Human Reliability Program Activities and Analyses," presentation at NRC Commission briefing, May 29, 2014.

"Public Confidence and Force-on-Force Inspections," presentation at the NRC Regulatory Information Conference, March 13, 2014.

"Fukushima: The Story of a Nuclear Disaster," lecture at the Carter Presidential Library, Atlanta,

GA, February 10, 2014.

“UCS Views on NTTF Recommendation 1 and the NRC Staff Proposal,” presentation at NRC Commission briefing, January 10, 2014.

“UCS Perspective on Expedited Transfer of Spent Fuel to Dry Casks,” presentation at NRC Commission briefing, January 6, 2014.

“Security Impacts of Emerging Nuclear Technologies,” MITRE STEP Technical Exchange, McLean, VA, December 3, 2013.

“UCS Perspective on Considering Economic Consequences in the NRC’s Regulatory Framework,” presentation at NRC Commission briefing, September 11, 2012.

“Lessons from Fukushima for Improving Nuclear Safety,” American Physical Society March Meeting, Boston, MA, March 1, 2012.

“Lessons from Fukushima for Improving Nuclear Safety,” Physics Department Colloquium, University of Central Florida, February 24, 2012.

Testimony on the Blue Ribbon Commission Report before the House Committee on Energy and Commerce, Subcommittee on Environment and the Economy, February 1, 2012.

“UCS Perspective on the Prioritization of NTTF Recommendations,” presentation at NRC Commission briefing, October 11, 2011.

“UCS Perspective on the Japan Task Force Report Short-Term Actions,” presentation at NRC Commission briefing, September 14, 2011.

Testimony on small modular reactors before the Senate Committee on Appropriations, Energy and Water Subcommittee, July 14, 2011.

Testimony on nuclear power legislation before the Senate Energy and Natural Resources Committee, June 7, 2011.

Testimony on the U.S. government response to Fukushima before the House Energy and Commerce Committee, Subcommittee on Oversight and Investigations, April 6, 2011.

Testimony on nuclear safety and Fukushima before the Senate Committee on Environment and Public Works, March 16, 2011.

“UCS Perspective on Maintaining Enhanced Safety for New Reactors,” presentation at NRC Commission briefing, October 14, 2010.

“Limiting Future Proliferation and Security Risks,” presentation to the Blue Ribbon Commission on America’s Nuclear Future, Reactor and Fuel Cycle Technology Subcommittee, October 12, 2010.

“Opportunities in Reactor and Fuel Cycle Technologies ,” presentation to the Blue Ribbon Commission on America’s Nuclear Future, Reactor and Fuel Cycle Technology Subcommittee, August 30, 2010.

“Proliferation and Terrorism Risks of the ‘Nuclear Renaissance,’” New York State American Physical Society meeting, April 24, 2010.

“Reprocessing in the U.S.: Just Say No,” presentation at the NRC Fuel Cycle Information Exchange, June 25, 2009.

“Nuclear Concerns: Safety, Security, Waste and Proliferation,” presentation at the Nuclear Nonoperating Owners’ Group Conference, Baltimore, MD, April 23, 2009.

“NRC Regulation of the Nuclear Fuel Cycle: Safety and Security Concerns,” presentation at the NRC Regulatory Information Conference, March 11, 2009.

“UCS Views on Risk-Informed Regulation,” presentation at NRC Commission briefing, February 4, 2009.

“Licensing Challenges for Fuel Cycle Facilities Under the Global Nuclear Energy Partnership,” U.S. Nuclear Regulatory Fuel Cycle Information Exchange, Rockville, MD, June 12, 2007.

“The ‘Nuclear Renaissance’ and the Spread of Nuclear Weapons,” American Physical Society Ohio Chapter Meeting, May 7, 2007.

“Recycling Nuclear Waste,” American Physical Society Annual April Meeting, Jacksonville, FL, April 15, 2007.

“The Security Imperative of Eliminating Commercial Use of HEU,” presentation to the Committee on Medical Isotope Production Without Highly Enriched Uranium, National Academy of Sciences, Washington, DC, February 15, 2007.

“Recycling Nuclear Waste,” Peace Studies Seminar, Cornell University, November 29, 2006.

“Nuclear Power and Nuclear Proliferation,” Citizens for Global Solutions conference, Washington, DC, November 13, 2006.

“Next-Generation Nuclear Plants: Safety and Security,” presented at “Is Nuclear Power a Solution to Global Warming and Rising Energy Prices?,” American Enterprise Institute conference, Washington, DC, October 6, 2006.

“Recycling Nuclear Waste: Technical Difficulties and Proliferation Concerns,” Physics Department Colloquium, Case Western Reserve University, Cleveland, OH, September 14, 2006.

“The Chernobyl Source Term: Implications for Nuclear Safety,” international conference

“Chornobyl +20: Remembrance for the Future,” Kiev, Ukraine, April 23-25, 2006.

“Public Health Consequences of a Severe Accident or Attack at a Nuclear Plant,” Nuclear Policy Research Institute Conference on Nuclear Power and Global Warming, Airlie House, Warrenton, VA, November 7, 2005.

Testimony before the Subcommittee on Clean Air, Climate Change on Nuclear Safety, Committee on Environment and Public Works, United States Senate, May 26, 2005.

“Safeguarding the U.S. Plutonium Disposition Program Against Nuclear Terrorism,” Science and Global Security Program seminar, Woodrow Wilson School of Public and International Affairs, Princeton University, December 9, 2004.

“Status of the Security Regime for the U.S. Mixed-Oxide Fuel Program,” Managing the Atom Project seminar, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, November 2, 2004.

"U.S. Nonproliferation Policy, Plutonium Disposition and the Threat of Nuclear Terrorism," seminar on "Recycling Plutonium: Risks and Alternatives," sponsored by the Green Group, European Parliament, Brussels, Belgium, January 9, 2003.

"Current Status of the U.S. Plutonium Disposition Program," seminar, Princeton University Program on Science and Global Security, Princeton University, Princeton, NJ, June 12, 2002.

"Controlling Fissile and Radioactive Material," Public Health Summit on Weapons of Mass Destruction, sponsored by Physicians for Social Responsibility and the UCLA School of Public Health, UCLA, Los Angeles, June 2, 2002.

"Assessing the U.S. Government Response to the Nuclear Terrorism Threat After 9/11," presentation to the Joint Atomic Energy Intelligence Committee, McLean, VA, May 9, 2002.

"Upgrading Physical Protection at Nuclear Facilities to Address New Threats," MIT Security Studies Seminar, MIT, Boston, MA, April 18, 2002.

"Perspectives on New Plant Licensing," presentation at the U.S. Nuclear Regulatory Commission Briefing on Readiness for New Plant Applications and Construction, Washington, DC, July 19, 2001.

"Regulatory Challenges for Future Nuclear Plant Licensing: A Public Interest Perspective," U.S. NRC Advisory Committee on Reactor Safeguards (ACRS) Workshop on New Nuclear Plant Licensing, Washington, DC, June 5, 2001.

"The Future of Nuclear Power: A Public Interest Perspective," 2001 Symposium of the Northeast Chapter of Public Utility Commissioners, Mystic, CT, May 21, 2001.

Statement at the U.S. Nuclear Regulatory Commission Briefing on Office of Nuclear Regulatory Research Programs and Performance, May 11, 2001.

"Barriers to Deployment of Micro-Nuclear Technology," presentation at the workshop on "New Energy Technologies: A Policy for Micro-Nuclear Technologies," James A. Baker III Institute for Public Policy, Rice University, Houston, TX, March 19-20, 2001.

"Aging Research and Public Confidence," presentation at the U.S. Nuclear Regulatory Commission 2001 Regulatory Information Conference (RIC), Washington, DC, March 14, 2001.

"NRC Reactor Safeguards Activities," presentation at the U.S. Nuclear Regulatory Commission 2001 Regulatory Information Conference (RIC), Washington, DC, March 14, 2001.

"DOE's Nuclear Material Stabilization Approach: The Failure of Transparency," Embedded Topical Meeting on DOE Spent Nuclear Fuel and Fissile Material Management, American Nuclear Society Annual Meeting, San Diego, CA, June 2000.

"The Status of Reactor Safeguards Initiatives," presentation at the U.S. NRC 2000 Regulatory Information Conference, Washington, DC, March 29, 2000.

"Safety Questions Concerning MOX Fuel Use in Proposed U.S. Reactors," Sixth International Policy Forum on the Management and Disposition of Nuclear Weapons Materials, sponsored by Exchange/Monitor Publications, Washington, DC, June 1999.

"Transparency and Plutonium Disposition," ISIS Workshop on Comprehensive Controls on Plutonium and Highly Enriched Uranium: Long-Term Problems and Prospects for Solutions, sponsored by the Institute for Science and International Security, Washington, DC, June 1997.

"Ship Transportation of Radioactive Materials," presentation to the Marine Board of the National Research Council, U.S. National Academy of Sciences, Woods Hole, MA, June 20, 1996.

"The Importation and Storage of High-Level Radioactive Wastes at Rokkasho-Mura: Safety Concerns," presentation at the Public Forum on High-Level Nuclear Waste and Reprocessing, Aomori, Japan, April 16, 1996.

"Perspectives on U.S. Options for Disposition of Excess Plutonium," Third International Policy Forum on the Management and Disposition of Nuclear Weapons Materials, sponsored by Exchange/Monitor Publications, Landsdowne, VA, March 21, 1996.

"Addressing Safety Issues in the Sea Transport of Radioactive Materials," presentation to the Special

Consultative Meeting of Entities Involved in the Marine Transport of Nuclear Materials Covered by the INF Code," International Maritime Organization, London, March 4-6, 1996.

"Prospects and Unsolved Issues for Plutonium Immobilization," INESAP/IANUS/UNIDIR Fissile Cutoff Workshop, Palais des Nations, Geneva, June 1995.

"An Intermediate Solution for Plutonium from Dismantled Nuclear Warheads," Annual Meeting of the German Physical Society, Berlin, Germany, March 1995.

"The Sea Transport of High-Level Radioactive Waste: Environmental and Health Concerns," Channel Islands International Conference on Nuclear Waste, St. Helier, Jersey, United Kingdom, January 1995.

Conference Papers

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E. Lyman, "Is Dilution the Solution to the Plutonium Threat?" 52th Annual Meeting of the Institute of Nuclear Materials Management, Palm Desert, CA, July 2011.

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E. Lyman, "Terrorism Threat and Nuclear Power: Recent Developments and Lessons to be Learned," Symposium on Rethinking Nuclear Energy and Democracy after 9/11, sponsored by PSR/IPPNW Switzerland, Basel, Switzerland, April 2002.

E. Lyman, remarks for Expert Panel on Advanced Reactors, Nuclear Safety Research Conference, U.S. Nuclear Regulatory Commission, Washington, DC, October 2001.

E. Lyman, "The Future of Immobilization Under the U.S.-Russian Plutonium Disposition Agreement," 42nd Annual Meeting of the Institute of Nuclear Materials Management (INMM), Indian Wells, CA, July 18, 2001.

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E. Lyman, "Can the Proliferation Risks of Nuclear Power be Made Acceptable?" Nuclear Control Institute 20th Anniversary Conference, Washington, DC, April 9, 2001.

E. Lyman and P. Leventhal, "Radiological Sabotage at Nuclear Power Plants: A Moving Target Set," 41st Annual Meeting of the INMM, New Orleans, LA, July 2000.

E. Lyman, "Comments on the Storage Criteria for the Storage and Disposal of Immobilized Plutonium," Proceedings of the Institute for Science and International Security Conference on "Civil Separated Plutonium Stocks --- Planning for the Future," March 14-15, 2000, Washington, DC, Isis Press, 135.

E. Lyman, "The Sea Shipment of Radioactive Materials: Safety and Environmental Concerns," Conference on Ultrahazardous Radioactive Cargo by Sea: Implications and Responses, sponsored by the Maritime Institute of Malaysia, Kuala Lumpur, Malaysia, October 1999.

E. Lyman, "A Critique of Physical Protection Standards for Irradiated Materials," 40th Annual Meeting of the INMM, Phoenix, AZ, July 1999.

E. Lyman, "DOE Reprocessing Policy and the Irreversibility of Plutonium Disposition," Proceedings of the 3rd Topical Meeting on DOE Spent Nuclear Fuel and Fissile Materials Management, American Nuclear Society, Charleston, SC, September 8-11, 1998, 149.

E. Lyman, "Japan's Plutonium Fuel Production Facility (PFPF): A Case Study of the Challenges of Nuclear Materials Management," 39th Annual Meeting of the INMM, Naples, FL, July 1998.

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E. Lyman, "Assessing the Proliferation and Environmental Risks of Partitioning-Transmutation," Fifth International Summer Symposium on Science and World Affairs, Cambridge, MA, USA, July 1993.

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P. Leventhal and E. Lyman, "Shipping Plutonium," New York Times, July 12, 2002.

- E. Lyman, "Indian Point Reactor," New York Times, January 27, 2002.
- E. Lyman, "Spent Nuclear Fuel," New York Times, June 3, 2001.
- E. Lyman and P. Leventhal, "Better Plutonium Plan," New York Times, February 5, 1998.
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- P. Leventhal and E. Lyman, "Who Says Iraq Isn't Making a Bomb?" International Herald Tribune, November 2, 1995.
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- E. Lyman, "Getting Rid of Weapon Plutonium," *Bulletin of the Atomic Scientists*, July/August 1994.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)	
)	
Tennessee Valley Authority)	Docket No. 52-047-ESP
)	
(Clinch River Nuclear Site))	
)	

**DECLARATION OF DR. M.V. RAMANA IN SUPPORT OF
PETITIONERS' CONTENTION 3 (IMPERMISSIBLE DISCUSSION OF
ENERGY ALTERNATIVES AND TECHNICAL ADVANTAGES)**

Under penalty of perjury, M.V. Ramana declares as follows:

1. My name is M.V. Ramana. I am a Professor and the Simons Chair in Disarmament, Global and Human Security at the Liu Institute for Global Issues, University of British Columbia, Vancouver, Canada.
2. I am a qualified expert on matters relating to nuclear energy policy and economics. I have a Ph.D. in Theoretical Physics from Boston University and a M.Sc. in Physics from the Indian Institute of Technology, Kanpur, India. I have written many academic papers and articles on a wide range of topics relating to nuclear energy in various journals and magazines, including *Scientific American*, *Science and Global Security*, *Energy Policy*, *Nuclear Technology*, *Journal of Risk Research*, *Environmental Impact Assessment Review*, *Energy Research and Social Science*, and *International Journal of Global Energy Issues*. I have also been a member of many professional organizations relevant to my area of expertise, including the International Panel on Fissile Materials and the Science and Security Board of the Bulletin of the Atomic Scientists. A copy of my curriculum vitae is attached.
3. I am familiar with the licensing-related filings and correspondence that have been submitted by Tennessee Valley Authority ("TVA") in support of its application for an Early Site Permit for a Small Modular Reactor ("SMR") on the Clinch River Nuclear Site, particularly TVA's Environmental Report. I am also familiar with applicable regulations, policies, and guidance documents of the U.S. Nuclear Regulatory Commission ("NRC").
4. I am familiar with the history of development of nuclear technology in the United States, including the development and operation of light water reactors and the development of SMR designs. I am also familiar with the characteristics and costs of a range of technologies available or currently being developed for electricity generation,

including coal and gas based power plants; renewable energy sources such as solar and wind; and nuclear energy. I have researched and written papers on various technical and policy issues related to SMRs, including their technical characteristics, uranium fuel requirements and spent fuel generation, challenges with their licensing, conflicts between design priorities, and demand for them in developing countries.

5. I assisted Petitioners with the preparation of their Contention 3, which asserts that TVA has failed to comply with the National Environmental Policy Act (“NEPA”) and NRC implementing regulations in its evaluation of alternatives. The factual assertions in the contention are true and correct to the best of my knowledge, and the opinions expressed therein are based on my best professional judgment.

M. V. Ramana

M.V. Ramana, Ph.D.

June 8, 2017

CURRICULUM VITAE

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Liu Institute for Global Issues
University of British Columbia

EMPLOYMENT

Simons Chair in Disarmament, Global and Human Security, Liu Institute for Global Issues, University of British Columbia	January 2017 onwards
Professional Specialist, Program in Science and Global Security, Princeton University Researching issues related to nuclear power, nuclear proliferation and climate change	July 2012 – December 2016
Associate Research Scholar, Program in Science and Global Security, Princeton University Researching issues related to nuclear power, nuclear proliferation and climate change	November 2009 – June 2012
Lecturer, Woodrow Wilson School of Public and International Affairs Designed and taught courses related to energy, environment and development, and nuclear power for Masters students and Freshmen	March 2010 – May 2012, Fall 2013, Fall 2014, Spring 2016
Visiting Research Scholar, Program in Science, Technology, and Environmental Policy, Woodrow Wilson School of Public and International Affairs, Princeton University Researching issues related to nuclear power and climate change	May 2009 – November 2009
Senior Fellow, Centre for Interdisciplinary Studies in Environment and Development, Bangalore	April 2007 – April 2009
Fellow, Centre for Interdisciplinary Studies in Environment and Development, Bangalore Researched economic and environmental aspects of India's nuclear energy program	April 2004 – April 2007
Research Staff, Program on Science and Global Security, Princeton University Researched global nuclear disarmament and India's nuclear weapons and energy programs	September 2001 – March 2004
Lecturer, Woodrow Wilson School of Public and International Affairs, Princeton University Lectured and conducted precepts for a course on Methods in Science, Technology, and Environmental Policy	September 2001 – February 2002
Lecturer, Yale Center for International and Area Studies, Yale University Designed and taught course on Science, Technology, and Development in India	August 2001 – December 2001
Research Associate, Center for Energy and Environmental Studies, Princeton University	September 1998 – August 2001

Conducted research on technical aspects of nuclear disarmament and India's nuclear weapons and energy programs; influence of scientists on nuclear policy

Lecturer, Woodrow Wilson School of Public and International Affairs, Princeton University February 1999 – July 1999
Gave lectures and conducted precepts for a course on Science, Technology, and Public Policy

Post-doctoral Fellow, Security Studies Program, Massachusetts Institute of Technology August 1996 – August 1998
Conducted research on technical aspects of nuclear weapons and disarmament, Indian ballistic missiles, and India's nuclear policy

Post-doctoral Fellow, Physics Department, University of Toronto September 1994 - July 1996
Conducted theoretical research on tests of particle physics models at accelerator experiments

Research Fellow, Physics Department, Boston University June 1989 – August 1994
Conducted research on phenomenological aspects of electroweak symmetry breaking

EDUCATION

Boston University, Ph.D., Physics, September 1994 Thesis Advisor: Kenneth D. Lane
Thesis Title: "Phenomenological Aspects of Electroweak Symmetry Breaking"

Indian Institute of Technology, Kanpur, M.Sc. Physics, May 1988

HONORS, AWARDS, PROFESSIONAL SERVICE

Distinguished Lecturer, Sigma Xi Society, 2016-17

Leo Szilard Award, American Physical Society, 2014

Member, International Panel on Fissile Materials, since 2005

Member, Science and Security Board of the Bulletin of Atomic Scientists, 2008-2014

Member, Editorial Board, *Energy Research and Social Science*, since 2015

Robert Jay Lifton Fellowship, John Jay College of Criminal Justice, City University of New York, 2005

Guggenheim Fellowship, 2003

Member, Selection Committee, Global Security and Cooperation Program, Social Sciences Research Council, 2000-01

MacArthur Foundation Research and Writing Grant, 1999

SSRC-MacArthur Fellowship for International Research on Peace and Security, 1999

SSRC-MacArthur Post-doctoral Fellowship on Peace and Security in a Changing World, 1996

National Talent Search Scholarship, 1981 -1988

Reviewed papers for several journals including *Science and Global Security*, *World Politics*, *Bulletin of the Atomic Scientists*, *Climate Policy*, *Energy Policy*, *Journal of Environment and Development*, *Sustainability*, *Global Environmental Change*, *Energy and Environmental Science*, *Social Science Journal*, *Environment, Development and Sustainability*, *Environmental Politics*, *Energy Research and Social Science*, *Journal of Risk Research*, *Economic and Political Weekly*, and *Energy for Sustainable Development*.

PUBLICATIONS

Refereed Publications

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M. V. Ramana, A. H. Nayyar, and Michael Schoeppner, “Nuclear High-level Waste Tank Explosions: Potential Causes and Impacts of a Hypothetical Accident at India’s Kalpakkam Reprocessing Plant,” *Science and Global Security*, **24**, no. 3 (2016), 174-203.

M. V. Ramana and Priscilla Agyapong, “Thinking Big? Ghana, Small Reactors, and Nuclear Power,” *Energy Research and Social Science*, **21** (2016), 101-113.

M. V. Ramana and Ali Ahmad, “Wishful Thinking and Real Problems: Small Modular Reactors, Planning Constraints, and Nuclear Power in Jordan,” *Energy Policy*, **93** (2016), 236–245.

Amy King and M. V. Ramana, “The China Syndrome? Nuclear Power Growth and Safety After Fukushima,” *Asian Perspective*, **39** (2015), 607-636.

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Benjamin Sovacool and M. V. Ramana, “Back to the Future: Small Modular Reactors, Nuclear Fantasies, and Symbolic Convergence,” *Science, Technology, and Human Values*, **40**, no. 1 (2015), 96-125.

M. V. Ramana and Zia Mian, “One Size Doesn't Fit All: Social Priorities and Technical Conflicts for Small Modular Reactors,” *Energy Research and Social Science* **2** (May 2014), 115-124.

Ali Ahmad and M. V. Ramana, “Too Costly to Matter: Economics of Nuclear Power for Saudi Arabia,” *Energy* **69** (May 2014), 682-694.

M. V. Ramana, Laura Berzak Hopkins, and Alexander Glaser, “Licensing Small Modular Reactors,” *Energy* **61**, (November 2013), 555-564.

M. V. Ramana and Ashwin Kumar, “‘One in Infinity’: Learning from Accidents and Lessons for Nuclear Safety in India,” *Journal of Risk Research* (2013), 23-42.

Alexander Glaser, Laura Berzak Hopkins, and M. V. Ramana, “Resource Requirements and Proliferation Risks Associated with Small Modular Reactors,” *Nuclear Technology* **184**, (October 2013), 121-129.

M. V. Ramana, “Shifting Strategies and Precarious Progress: Nuclear Waste Management in Canada,” *Energy Policy* **61**, (October 2013), 196-206.

M. V. Ramana and Eri Saikawa, “Choosing a Standard Reactor: International Competition and Domestic Politics in Chinese Nuclear Policy,” *Energy* **36** (2011), 6779-6789.

J. Y. Suchitra and M. V. Ramana, “The Costs of Power: Plutonium and the Economics of India’s Prototype Fast Breeder Reactor,” *International Journal of Global Energy Issues* **35**, no. 1 (2011), 1-23.

M. V. Ramana and Divya Badami Rao, “The Environmental Impact Assessment Process for Nuclear Facilities: An Examination of the Indian Experience,” *Environmental Impact Assessment Review* **30**, no. 4 (2010), 268-271.

- M. V. Ramana and Ashwin Kumar, “Least Cost Principles and Electricity Planning for Karnataka,” *Energy for Sustainable Development* **13**, no. 4 (2009), 225–234.
- M. V. Ramana and J. Y. Suchitra, “Slow and Stunted: Plutonium Accounting and the Growth of Fast Breeder Reactors in India,” *Energy Policy* **37**, no. 12 (2009), 5028-5036.
- M. V. Ramana “India and Fast Breeder Reactors,” *Science and Global Security* **17** (2009), 54-67.
- M. V. Ramana and Ashwin Kumar, “Compromising Safety: Design Choices and Severe Accident Possibilities in India's Prototype Fast Breeder Reactor,” *Science and Global Security* **16** (2008), 87-114.
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- M. V. Ramana, Antonette D'Sa, and Amulya Reddy, “Nuclear Energy Economics in India,” *Energy for Sustainable Development* **IX**, no. 2 (June 2005), 35-48.
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- Zia Mian, R. Rajaraman, and M. V. Ramana, “Early Warning in South Asia: Constraints and Implications,” *Science and Global Security* **11** (2003), 109–150.
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- B. Holdom and M. V. Ramana, “A New Physics Source of Hard Gluons in Top Quark Production,” *Physics Letters B* **353** (1995), 295-300.
- R. S. Chivukula, M. Golden, D. Kominis, and M. V. Ramana, “The Phenomenology of a Hidden Symmetry Breaking Sector,” *Physics Letters B* **293** (1992), 400-404.
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M. V. Ramana, “Constraints on India’s Fast Breeder Program,” in *51st Annual Meeting of the Institute of Nuclear Materials Management*, July 13, 2010, Baltimore, USA, 1-9.

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Suvrat Raju and M. V. Ramana, “Cost of Electricity from the Jaitapur Nuclear Power Plant,” *Economic and Political Weekly* **XLVIII**, no. 26 & 27 (2013), 51-60.

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Thomas Cochran, Harold Feiveson, Zia Mian, M. V. Ramana, Mycle Schneider, and Frank von Hippel, "It's Time to Give Up on Breeder Reactors," *Bulletin of the Atomic Scientists* **66**, no. 3, (May/June 2010), 50-56.

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M. V. Ramana and Ashwin Kumar, "Safety First? Kaiga and Other Nuclear Stories," *Economic and Political Weekly* **XLV**, no. 7 (2010), 47-54.

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Divya Badami Rao and M. V. Ramana, "Violating Letter and Spirit: Environmental Clearances for Koodankulam Reactors," *Economic and Political Weekly* **XLIII**, no. 51 (December 20, 2008), 14-18.

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U. A. Shimray and M. V. Ramana, "Uranium Mining in Meghalaya: Simmering Problem," *Economic and Political Weekly* **XLII**, no. 52 (December 29, 2007), 13-17.

M. V. Ramana, "Heavy Subsidies in Heavy Water: Economics of Nuclear Power in India," *Economic and Political Weekly* **XLII**, no. 34 (August 25, 2007), 3483-3490.

M. V. Ramana, "Economics of Nuclear Power: Subsidies and Competitiveness," *Economic and Political Weekly* **XLII**, no. 2 (January 13, 2007), 169-171.

J. Y. Suchitra and M. V. Ramana, "High Costs, Questionable Benefits of Reprocessing," *Economic and Political Weekly* **XLI**, no. 47 (November 25, 2006), 4848-4851.

M. V. Ramana, "Twenty Years after Chernobyl: Debates and Lessons," *Economic and Political Weekly* **XLI**, no. 18 (May 6, 2006), 1743-1747.

J. Y. Suchitra and M. V. Ramana, "Nuclear Power: No Route to Energy Security," *Energy Security Insights* **I**, no. 1 (March 2006), 13-16.

Zia Mian and M. V. Ramana, "Wrong Ends, Means, and Needs: Behind the U.S. Nuclear Deal with India," *Arms Control Today* (January/February 2006), 11-17.

M. V. Ramana, "Tall Claim, Little Evidence," *Economic and Political Weekly* **XL**, no. 50 (December 10, 2005), 5237-5239.

M. V. Ramana, "Nuclear Power: Expensive and Unsafe," *Electrical India* **45**, no. 11 (November 2005), 1-11.

Zia Mian and M. V. Ramana, "Feeding the Nuclear Fire," *Economic and Political Weekly* **XL**, no. 35 (August 27, 2005), 3808-3812.

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“Enduring Nuclear Legacies,” *The Daily Times*, July 17, 2003

“Steps to Peace,” *The Daily Times*, May 22, 2003

“Remembering the Chernobyl Catastrophe,” *The Daily Times*, April 24, 2003

“Compounding Mistakes: New Reactor at Chashma,” *The Daily Times*, April 10, 2003

“Assessing Emergency Plans,” *The Daily Times*, March 13, 2003

“Nuclear Resurgence in the US,” *The Daily Times*, February 27, 2003

“India’s Force in Being,” *The Daily Times*, February 6, 2003

“Phasing Out Nuclear Energy in Europe,” *The Daily Times*, January 30, 2003

“Military Planning and Nuclear Weapons,” *The Daily Times*, January 16, 2003

“India’s Nuclear Command Authority,” *The Daily Times*, January 9, 2003

“Reckless Challenges,” *The Daily Times*, December 5, 2002

“Following the US Lead,” *The Daily Times*, November 14, 2002

“False Alarms and Early Warning Systems,” *The Daily Times*, November 7, 2002

“North Korea’s Negotiating Strategy,” *The Daily Times*, October 31, 2002

“Deterrence: Hope and Reality,” *The Daily Times*, October 3, 2002

“Nuclear Deterrence: The Inside Look,” *The Daily Times*, September 26, 2002

“Shared Understandings and Deterrence,” *The Daily Times*, September 12, 2002

“Impacts of Underground Nuclear Tests,” *The Daily Times*, August 23, 2002

“The Arrow Deal: India, Israel and the US,” *The Daily Times*, August 8, 2002

“Indo-Pak Military Crises – Some Fallout,” *The Daily Times*, July 25, 2002

“Censorship in the Nuclear Age,” *The Hindu*, July 19, 2002

“Radioactive Fallout from Nuclear Testing,” *The Daily Times*, July 18, 2002

“Bush-Putin Nuclear Treaty,” *The Daily Times*, July 4, 2002

“Censoring Nuclear Truths,” *The Daily Times*, June 27, 2002

“The Illogic of Civil Defense,” *The Daily Times*, June 13, 2002

“Tactical Nuclear Weapons: Another Firebreak,” *The Daily Times*, June 6, 2002

“Profiting from Arms Sales and Death,” *The Daily Times*, May 30, 2002

“Nuclear Instability and Militancy,” *The Daily Times*, May 23, 2002

“Missiles and the Fast Delivery of Nuclear Destruction,” *The Daily Times*, May 16, 2002

“Looking Back at Pokharan II,” *Outlook (web edition)*, May 13, 2002

“Dubious Achievements of the BJP Government,” *The Daily Times*, May 9, 2002

“Nuclear Non-Proliferation Treaty: Stalemate again,” *The Daily Times*, April 25, 2002

“The US Contempt for International Treaties,” *The Daily Times*, April 18, 2002

“Reviewing the Nuclear Non-Proliferation Treaty,” *The Daily Times*, April 11, 2002

“Reality Behind the Smoke Screen: US Nuclear Posture Review,” *The Friday Times*, April 5-11, 2002

“In the Event of a Nuclear War,” *Mantram: For the Ambitious South Asian Professional*, March 2002

“India-Pakistan Standoff: Recalling October 1962,” *The Friday Times*, February 22-28, 2002

“A Nuclear Wedge,” *Frontline*, December 8, 2001

“India, Pakistan and the Bomb,” with A. H. Nayyar, *Scientific American*, December 2001

“Yet Another Nuclear Danger,” with Zia Mian and R. Rajaraman, *Frontline*, August 17, 2001

“Fast Breeders: Tall Promises, Poor Performance,” *The Hindu*, July 16, 2001

“What they can Agree on,” *The Hindu*, July 10, 2001

“The New Texas Ranger and his Guns,” with Andrew Lichterman, *Frontline*, June 8, 2001

“Fast-breeder Reactors - A Dying Breed,” *The Hindu*, May 28, 2001

“The Bomb of the Blue God,” *South Asian Magazine for Action and Reflection*, Winter/Spring 2001

“Slow, Silent Killer,” *Frontline*, February 3, 2001

“New Nukes, Old Speak,” *The Friday Times*, October 27, 2000

“The Concorde and the Nuclear Reactor,” *Himal*, September 2000

“Ending the n-race,” *The Hindu*, May 25, 2000

“Old Weapons, New Contestants,” *IEEE Spectrum*, March 2000

“Scientists and the Indian Bomb,” *Anubhav*, February 2000

“The Question of Nuclear Yield,” *Frontline*, January 21, 2000

“Dangerous Encounters: Nuclear Reactor Accidents,” *The Hindu*, November 21, 1999

“Organizing in India Against the Bomb,” *Vital Signs*, Vol. 12, Issue 2, November 1999

“Sweeping Charges: The Cox Report and Nuclear Espionage,” *Frontline*, October 22, 1999

“Draft Nuclear Doctrine,” *Dainik Bhaskar (Hindi)*, September 1999

“A Recipe for Disaster,” *The Hindu*, September 9, 1999

“Disturbing Questions: On the Heavy Water Leak at the Madras Atomic Power Station,” *Frontline*, June 4, 1999

“Underground Tests: Ravaging Nature,” *The Hindu Survey of the Environment '99* (June 1999)

“Heads They Win, Tails We All Lose,” *Dainik Bhaskar (Hindi)*, June 1999

“Nuclear Tests: the Long Term Fallout,” *The News on Sunday (Pakistan)* May 2, 1999

“For a Just Peace: The Anti-Nuclear Movement in India,” *Social Science Research Council Newsletter* 12 (May 1999)

“Health and Environmental Effects of Underground Nuclear Tests,” *Dainik Bhaskar (Hindi)*, March 1999

“Radiation Perils to Workers: Experiences from the United States,” *Dainik Bhaskar (Hindi)*, February 1999

“Reject the Hydrogen Bomb!,” *Dainik Bhaskar (Hindi)*, January 1999

“Did India Test an H-bomb?,” with Frank von Hippel, *Federation of American Scientists Public Interest Report* **52** No. 1, January/February 1999

“Does India Need the H-bomb?,” with Frank von Hippel, *The Hindu*, December 23, 1998

“Nuclear Weapons and Security,” *Dainik Bhaskar (Hindi)*, December 1998

“The Indian Nuclear Bomb – Long in the Making,” *Precis* **9** No. 3 Fall 1998

“If? Bombing Bombay,” *Himal* August 1998

“India's Changing Nuclear Policy,” *Peace Magazine* XIV, January/February 1998

“A Fissile Material Cutoff Treaty,” *Peace Magazine* XII, May/June 1996

PROFESSIONAL MEETINGS

- “Global and Regional Economics of Nuclear and Renewable Energy,” Presentation at Workshop on The Future of Nuclear Energy in the Middle East, International Panel on Fissile Materials and American University of Beirut, Beirut, March 15, 2017
- “Nuclear Energy in Saudi Arabia: Necessary? Economically Competitive?,” Presentation at NPEC Public Policy Fellowship Retreat, Nonproliferation Policy Education Center, Washington, D.C., March 4, 2017
- “Linkages Between Nuclear Energy and Nuclear Weapons,” Presentation (over Skype) at Workshop on The Nuclear-Climate Nexus and Sustainable Peace, International Peace Bureau World Congress, Berlin, October 1, 2016
- “Emerging Reactor and Fuel Cycle Technologies, Including Associated Safety, Security, and Safeguards Risks,” Presentation at Workshop on Managing Risks Associated with Global Nuclear Energy Expansion: Emerging Challenges and Cooperative Solutions, George Washington University, Washington, D. C., May 5, 2016
- “Reprocessing and Breeder Reactors: The Case of India,” Presentation at Meeting of the International Panel on Fissile Materials, American Association for the Advancement of Science, Washington, D. C., March 14-15, 2016
- “Ethical Concerns Regarding Nuclear Energy: Weapons, Accidents, Wastes, Costs, and Democracy,” Workshop on Ethics and Governance of Energy Technologies, Eindhoven University of Technology, Netherlands, January 15, 2016
- Co-convenor, Working Group on “Civilian Nuclear Energy, Energy Resources, and International Cooperation,” 61st Pugwash Conference on Science & World Affairs, Nagasaki, Japan, November 1-5, 2015
- “Small Modular Reactors in the United States,” Workshop on Nuclear Power And Small Modular Reactors In Indonesia: Potential And Challenges, Indonesian Institute of Energy Economics, Jakarta, June 25, 2015
- “The Challenges of Nuclear Safety,” International Workshop on Emerging Energy Scenarios in the Middle East, Munib and Angela Masri Institute of Energy and Natural Resources, American University, Beirut, May 22, 2015
- “Accident Risks for High Temperature Reactors,” 1st International Conference on Nuclear Risks, Vienna, April 16-17, 2015
- “Taking Sides on the ‘Double Movement’,” Polanyi Conference on Science and Social Responsibility, University of Toronto, November 15, 2014
- “Nuclear Power in Today’s Energy and Environmental Discourse,” Workshop on New Studies in Ecology and Environment, New Delhi, India, August 23, 2014
- “Liability” and “Waste Management,” two talks at Workshop on Nuclear Power in East Asia: The Costs and Benefits, Australian National University, Canberra, Australia, August 12-14, 2014
- “The State of the SMR Market,” Third Trilateral Meeting, Carnegie Mellon University, Pittsburgh, May 8-9, 2014
- “Arguing from the Periphery,” American Physical Society Annual Meeting, Savannah, GA, April 6, 2014

- “Resource Requirements and Proliferation Risks Associated with Small Modular Reactors,” Panel on Opportunities and Challenges for Nuclear Small Modular Reactors, American Association for the Advancement of Science Annual Meeting, Chicago, February 15, 2014
- “Global Context for Nuclear Power,” Conference on Nuclear Technology, Nuclear Energy and a ME WMD-free Zone, Doha, Qatar, October 27, 2013
- “The Impact of Fukushima and Chernobyl on India’s Anti-Nuclear Movements,” Conference on Traveling Norms and the Politics of Contention, Zurich, Switzerland, October 25, 2013
- “Small Modular Reactors: Uranium Resource Requirements, Waste Generation and Proliferation Risk Assessment,” Presentation at the 21st International Conference on Nuclear Engineering, Chengdu, China, July 29-August 2, 2013
- “Fukushima Nuclear Accident: Shortcomings of Safety Regulation and Lessons Learned,” Panel Discussion at the Carnegie International Nuclear Policy Conference, Washington, D.C., April 8, 2013
- “Whither Nuclear Power?” Panel Discussion at the Carnegie International Nuclear Policy Conference, Washington, D.C., April 8, 2013
- “‘One in infinity’: Assessing Nuclear Risks in India,” Presentation at the Panel on “India at Risk: Capacity, Institutions and Expertise”, Society for Risk Analysis 2012 Annual Meeting, San Francisco, December 12, 2012
- “How about Domestic Emission Inequities? The Case of India,” Presentation at the International Conference on Inequality and Sustainability, Stockholm Environmental Institute & Center for International Environment and Resource Policy, Boston, November 9, 2012
- “Proliferation Risks Associated with Small Modular Reactors,” Presentation at the “Summer Symposium on Science and World Affairs”, Organized by the Union of Concerned Scientists, Princeton, July 9, 2012
- “India and Nuclear Transparency,” Presentation at the Workshop on “Transparency”, Organized by the International Panel on Fissile Materials, Princeton, March 31, 2012
- “Nuclear Safety and Security in India,” Presentation at the Panel Discussion on Nuclear Policy of Key Countries, Seoul National University, Seoul, South Korea, March 22, 2012
- “Indian Fallout: Public Protest and Organizational Strategies in the Aftermath of the Fukushima Accidents,” Presentation at Panel Discussion on Nuclear Energy After Fukushima: Japan and Beyond, Association of Asian Studies Conference, Toronto, March 18, 2012
- “Nuclear Power in India: Implications of Fukushima,” Presentation at the Panel on Nuclear Power: One Year after Fukushima, American Physical Society Meeting, Boston, March 1, 2012
- “India’s Nuclear Plans: Can they be Realized?,” Presentation at the Workshop on “Reprocessing”, Organized by the International Panel on Fissile Materials, Tokyo, January 20, 2012
- “Prospects for India’s Breeder Program,” Presentation at the Workshop on “Nuclear Fuel Cycle Issues in Asia”, Organized by the International Panel on Fissile Materials, Tokyo, March 19, 2010
- “Inherently Ambiguous? The Limits of Nuclear Accident Scenarios and Safety Analyses,” Meeting on “Knowledge Society Debates”, Organized by the STEPS Centre, University of Sussex, National Institute of Advanced Studies, Bangalore, January 8, 2009
- “Some Challenges for Nuclear Power in Developing Countries,” Presentation at Conference on “New Generation Nuclear: From policy to implementation,” Organized by Chatham House, London, November 17-18, 2008

- “Nuclear Power in India: Perspectives and Challenges,” Presentation at Conference on “The nuclear energy revival: regional perspectives and governance challenges,” Organized by Centre for International Governance Innovation & Canadian Centre for Treaty Compliance, Waterloo, November 6-7, 2008
- “More than Desirable: Some Necessary, but not Sufficient, Conditions for Nuclear Expansion,” Presentation at the Conference on The Future of Nuclear Energy, Organized by the Bulletin of the Atomic Scientists, Argonne National Laboratory, and the University of Chicago, Chicago, September 25-26, 2008
- “Nuclear Power and Energy Security in India,” Presentation at Meeting on “The Proposal for Nuclear Trade with India,” Organized by Heinrich Böll Foundation and Arms Control Association, Berlin, May 13, 2008
- “Some Implications of the US-India Nuclear Deal,” Presentation at the NGO Panel on “The US-India Nuclear Deal and the NPT,” Nuclear Non Proliferation Treaty Preparatory Committee Meeting, United Nations, Geneva, May 2, 2008
- “Fissile Material Implications of the US-India Nuclear Deal,” Presentation at the Annual Meeting of the German Physical Society, Berlin, February 29, 2008
- “Nuclear Safety,” Presentation at the Centre for Interdisciplinary Studies on Environment and Development Advisory Committee Meeting, Bangalore, January 11, 2008
- “Climate Change and Nuclear Power in Developing Countries,” Presentation at “Nuclear Energy: Myth and Reality,” Side event at 13th Conference of Parties to the United Nations Framework Convention on Climate Change, Organized by Heinrich Böll Foundation, Nusa Dua, Bali, December 13, 2007
- “Infeasible and Undesirable: A Nuclear Comeback and Climate Security,” Presentation at 2nd TERI-KAF Conference on “Energy, Climate, and Security: The Inter-Linkages,” Organized by The Energy and Resources Institute and Konrad Adenauer Foundation, Goa, October 13 - 14, 2007
- “Nuclear Reactors: Unsafe at any Price,” Presentation at the International Conference on “Indo-US Nuclear Deal,” Organized by the Heinrich Böll Foundation, CNDP, and PEACE, New Delhi, August 31-September 1, 2007
- “The U.S. India Nuclear Deal: Debates and Implications,” Presentation at the Meeting on “Forging a New Consensus for the NPT,” Article VI Forum, Vienna International Center, Vienna, March 29, 2007
- “Nuclear Energy: Projections and Economics,” Presentation at Workshop on Power Sector Reforms and Regulation in India, Prayas, Pune, March 22-23, 2007
- “Economic and Environmental Costs of Nuclear Power,” Presentation at the Ninth Biennial Conference of the International Society of Ecological Economics, New Delhi, December 16-18, 2006
- “Nuclear Economics in a Developing Country: The Case of India,” Presentation at the Conference on The Future of Nuclear Energy, Organized by the Bulletin of the Atomic Scientists, Argonne National Laboratory, and the University of Chicago, Chicago, November 1-2, 2006
- “Nuclear Energy and Climate Change,” Presentation at the Workshop for Journalists on Energy and Climate Change, Organized by PANOS South Asia, New Delhi, July 5, 2006
- “Feeding the Nuclear Fire,” Presentation at the Conference on International Nuclear Cooperation with India, Simons Centre for Disarmament, University of British Columbia, Vancouver, November 22, 2005

- “India’s Nuclear Enclave and the Practice of Secrecy,” Presentation at the Second Workshop on “Culture, Society and Nuclear weapons in South Asia,” Social Science Research Council, Washington, D.C., August 28-29, 2005
- “An Estimate of India’s Uranium Enrichment Capacity,” Presentation at the 17th International Summer Symposium on Science and World Affairs, Princeton, July 23-31, 2005
- Discussant, First Workshop on “Culture, Society and Nuclear weapons in South Asia,” Social Science Research Council, Amsterdam, May 9-11, 2005
- “Nuclear Power: the Department of Atomic Energy’s Plans and Constraints,” Presentation at the Consultation Meeting on Strategies to Realize a Non-nuclear India organized by Citizens for Alternatives to Nuclear Energy and Centre for Interdisciplinary Studies in Environment and Development, Bangalore, January 29, 2005
- Coordinator, Environmental Sustainability Group, Workshop on “Neglected Dimensions of Electricity Sector Policies: Equity, Sustainability, and Institutions and Governance,” Prayas, Pune, January 11-12, 2005
- “India and Nuclear Secrecy,” Presentation at the Conference on “Transparency as a Pre-requisite of Arms Control,” Peace Research Institute, Bensheim, November 19-20, 2004
- “Nuclear Energy and Security,” Presentation at the Workshop on “The Challenge of Hiroshima: Alternatives to Nuclear Weapons, Missiles, Missile Defenses, and Space Weaponization in a Northeast Asian Context,” International Network of Engineers and Scientists Against Nuclear Weapons, Hiroshima, October 8-11, 2004
- “Energy and Environmental Sustainability,” Presentation at the National Seminar on Integrating Environmental Sustainability with Economic Development, Maharani’s Arts College for Women, Bangalore, August 26, 2004
- “The Cost of Electricity from Indian Pressurised Heavy Water Reactors,” Presentation at the Centre for Interdisciplinary Studies on Environment and Development Advisory Committee Meeting, Bangalore, January 12, 2004
- “Effects of Nuclear Explosions,” Lecture at the Workshop on “Defence, Technology and Cooperative Security in South Asia”, Regional Centre for Strategic Studies, Shanghai, December 3-13, 2003
- “Problems with Nuclear Early Warning Systems in South Asia,” Lecture at the Workshop on “Defence, Technology and Cooperative Security in South Asia”, Regional Centre for Strategic Studies, Shanghai, December 3-13, 2003
- “Nuclear Weapons Effects,” Presentation at the Institute for Energy and Environmental Research Technical Training Workshop, Takoma Park, Maryland, June 19, 2003
- “Nuclear South Asia,” Talk at Panel on “War and Public Health,” Presentation at the American Public Health Association 130th Annual Meeting & Exposition, Philadelphia, November 11, 2002
- “Under the Nuclear Shadow,” Discussion at Middlesex County College, October 31, 2002
- “Dangers of Nuclear War and Paths to Nuclear Weapons Abolition,” Presentation at the American Friends Service Committee Conference on “Paths to a Just and Secure Future,” Boston, October 11, 2002
- “Nuclear South Asia,” Overview Lecture at the 1st International Professional Meeting of Independent Technical Security Analysts, Chicago, July 23-24, 2002

- Invited “Shadow Expert” at the SANITY (Students Against Nuclear Insanity and for Tomorrow’s Youth) Youth Caucus at the Nuclear Non Proliferation Treaty Preparatory Committee Meeting, United Nations, New York, April 17, 2002
- “The Arms Race in South Asia,” Presentation at the NGO Panel on “The Shape of Things to Come,” Nuclear Non Proliferation Treaty Preparatory Committee Meeting, United Nations, New York, April 12, 2002
- “Alternatives to Missile Defense,” Briefing for Delegates, NGOs and Press at the Nuclear Non Proliferation Treaty Preparatory Committee Meeting, United Nations, New York, April 11, 2002
- “Effects of Nuclear Explosions and Nuclear War in South Asia,” Lecture at the Workshop on “Defence, Technology and Cooperative Security in South Asia”, Regional Centre for Strategic Studies, Kalutara, Sri Lanka, January 5-14, 2002
- “Plutonium Dispersal and Health Hazards from Nuclear Weapon Accidents,” Lecture at the Workshop on “Defence, Technology and Cooperative Security in South Asia”, Regional Centre for Strategic Studies, Kalutara, Sri Lanka, January 5-14, 2002
- “Beyond Missile Defense: Arguments,” Presentation at the 13th International Summer Symposium on Science and World Affairs, Berlin, July 21-30, 2001
- “The Missile Race in Critical Regions: Is there a way out?,” Presentation at the Workshop on “Moving Beyond Missile Defense”, International Network of Engineers and Scientists Against Nuclear Weapons, Santa Barbara, March 19-21, 2001
- “Is there a Missile Threat? The Dynamics of Missile Proliferation and the State of Missile Control,” Presentation at the Workshop on “Moving Beyond Missile Defense”, International Network of Engineers and Scientists Against Nuclear Weapons, Santa Barbara, March 19-21, 2001
- “Ballistic Missile Disarmament,” Presentation at the Panel on “Outer Space: Disarmament Issues,” Organized by the NGO Committee on Disarmament, Disarmament Week, United Nations, October 19, 2000
- “Why Nuclear Disarmament,” Presentation at the Alliance for Nuclear Accountability Meeting, Amarillo, September 23, 2000
- “Plutonium Dispersion and Health Hazards from Nuclear Weapons Accidents,” Presentation at the 12th International Summer Symposium on Science and World Affairs, Moscow, Russia, August 23-31, 2000
- “Scientists and Radiation Protection: A History,” Presentation at the NGO Panel on “Health, Environment, Science and Society: Professional Responsibility in the Nuclear Age,” Nuclear Non-Proliferation Treaty Review Conference, United Nations, New York, May 15, 2000
- “Environmental Aspects of the Nuclear Fuel Cycle,” Presentation at the NGO Panel on “The Toxic Legacy of the Nuclear Age,” Nuclear Non-Proliferation Treaty Review Conference, United Nations, New York, May 4, 2000
- “Scientists and Ideology,” Presentation at the NGO Panel on “Personal Responsibility in the Nuclear Age,” Nuclear Non-Proliferation Treaty Review Conference, United Nations, New York, May 1, 2000
- “NPT Forecast: Cloudy or Sunny,” Presentation at the NGO Presentation in preparation for the Nuclear Non-Proliferation Treaty Review Conference, United Nations, New York, April 18, 2000
- “The Future of Post-Nuclear South Asia,” Presentation at the Conference on “Rethinking the Past, Shaping the Future: Partition, History and Identity,” South Asian Students Association of Smith College, Northampton, MA, March 25, 2000

- Overview presentation at the workshop (jointly organized with Srirupa Roy, New York University) on “Nuclear Understandings: Science, Society, and the Bomb in South Asia,” Dhaka, February 17, 2000
- Overview presentation at plenary discussion on “Nuclear Policy and Understandings in India” at the 13th Annual SSRC-MacArthur Foundation Fellows' The Conference, New Delhi, August 19-23, 1999
- “Health Effects of Reactor Accidents,” Presentation at the 11th International Summer Symposium on Science and World Affairs, Shanghai, China, July 28 - August 5, 1999
- “Regional Proliferation,” NGO Presentation at the Nuclear Non Proliferation Treaty Preparatory Committee Meeting, United Nations, New York, May 10-21, 1999
- “Nuclear Capabilities of India,” Presentation at the session on “Physics and Disarmament” at the 63rd Annual Meeting of the German Physical Society, Heidelberg, March 18, 1999
- Keynote Speaker, Symposium on De-alerting of Nuclear Weapons, Organized by The United Nations Department of Disarmament Affairs, New York, October 26, 1998
- “Radioactivity Releases from Underground Nuclear Tests,” Presentation at the 10th International Summer Symposium on Science and World Affairs, Cambridge, Massachusetts, USA, July 13-21, 1998
- “India's Nuclear Tests: Some Technical Aspects,” Presentation at the 10th International Summer Symposium on Science and World Affairs, Cambridge, Massachusetts, USA, July 13-21, 1998
- “Effects of a Nuclear Explosion,” Presentation at the Institute for Energy and Environmental Research Technical Training Workshop, Takoma Park, Maryland, July 7-12, 1998
- Discussant, Panel Discussion on “India, Pakistan and Global Nuclear Disarmament,” Sponsored by Congresswoman Barbara Lee and Congressman John Conyers and the Institute for Policy Studies, Rayburn House Office Building, Washington, D.C., June 25, 1998
- “India's Nuclear Tests,” Presentation at the 12th Annual SSRC-MacArthur Foundation Fellows' Conference, San Salvador, May 17-23, 1998
- Invited Specialist to discuss “Agreements on controlling the components: a fissile material cut-off” at the International Consultation on “Global Security and Nuclear Disarmament” organized by the United Services Institution, Delhi and the Oxford Research Group, U.K., Neemrana, March 3-6, 1998.
- “Serving a Nuclear Summons: How to make the Nuclear Weapon States Negotiate Disarmament,” Presentation at the Pugwash Workshop on “Eliminating Nuclear Weapons,” New Delhi, March 1-3, 1998
- Participant, Meeting on “The Future of Russian-US Strategic Arms Reductions: START III and Beyond,” Jointly sponsored by The Center for Arms Control, Energy, and Environmental Studies, The Moscow Institute of Physics and Technology, and The MIT Security Studies Program, Cambridge, USA, February 2-6, 1998
- “Modelling Prithvi and Agni,” Presentation at the 9th International Summer Symposium on Science and World Affairs, Cornell University, Ithaca, USA, July 24 -August 3, 1997
- Participant, Conference on “The Future of Nuclear Weapons : A US-India Dialogue,” Center for Advanced Study of India, University of Pennsylvania, May 5-8, 1997
- “Nuclear Energy in India: Problems and Prospects,” Presentation at the NGO sessions of the NPT Preparatory Conference, United Nations, New York, USA, April 15, 1997

- “The Effects of Nuclear Explosions - a Case Study of Mumbai,” Presentation at the Regional Meeting of the International Physicians for the Prevention of Nuclear War, New Delhi, India, February 21-23, 1997
- “History of the Comprehensive Test Ban Treaty,” Overview Presentation at Panel Discussion on South Asia and the CTBT, Massachusetts Institute of Technology, USA, September 24, 1997
- “India's Participation in a Fissile Material Production Cutoff Convention,” Presentation at the 8th International Summer Symposium on Science and World Affairs, Beijing, China, July 23-31, 1996
- “India's Participation in a Fissile Material Production Cutoff Convention” Presentation at the 10th Annual SSRC-MacArthur Foundation Fellows' Conference, Oxford University, United Kingdom, May 18-23, 1996
- “New Flavor Physics in b Decays,” Presentation at the 2nd Workshop on High Energy Physics Phenomenology, SN Bose Institute, Calcutta, January 1996
- “A New Physics Source of Hard Gluons in Top Quark Production,” Presentation at the 17th Annual MRST Meeting on High Energy Physics, Rochester, NY, USA, May 8-9, 1995
- Participant, Theoretical Advanced Study Institute in Elementary Particle Physics, Boulder, Colorado, USA, June 2-28, 1991

INVITED SEMINARS AND LECTURES

- “The Nuclear Arms Race in South Asia: The Case of India,” Lecture in Course on Weapons of Mass Destruction and International Security, Princeton University, Princeton, April 10, 2017
- “Why do States Build Nuclear Weapons? The Case of India,” Carleton College, MN, November 4, 2016
- “Nuclear Power: Overview, Economics, and India,” Carleton College, MN, November 4, 2016
- “Small Modular Reactors: An Inadequate Response to the Challenges Faced by Nuclear Power,” Nanyang Technological University, Singapore, October 18, 2016
- “U.S. Launch of the World Nuclear Industry Status Report 2016,” with Mycle Schneider, Natural Resources Defense Council, Washington, D.C., September 19, 2016
- “After Fukushima: Nuclear Power Programs Around the World,” Google Hangout with Sigma Xi, October 11, 2016
- “Nuclear Weapons in South Asia: Programmes, Plans, and Dangers,” Dr. Asghar Ali Engineer Memorial Advisory Committee and Coalition for Nuclear Disarmament and Peace, Mumbai, August 27, 2016
- “The Future of Nuclear Energy in India: Expectations and Constraints,” School of Media and Cultural Studies, Tata Institute of Social Sciences, Mumbai, August 26, 2016
- “Understanding Nuclear Energy and Nuclear Diplomacy,” Asian College of Journalism, Chennai, August 22, 2016
- “Whither Nuclear Power in the Middle East: The Cases of Saudi Arabia and Jordan,” Nonproliferation Policy Education Center, Washington, D.C., May 5, 2016
- “Connections Between Nuclear Energy and Nuclear Weapons,” Liu Institute for Global Issues, University of British Columbia, Vancouver, January 8, 2016
- “Exit, Voice, and Loyalty: Policy Choices and the Future of Nuclear Energy since Fukushima,” Liu Institute for Global Issues, University of British Columbia, Vancouver, January 7, 2016
- “Nuclear Power and India’s Energy Needs: Lessons from History,” Energy Policy Institute at the University of Chicago- India Centre, New Delhi, December 23, 2015
- “Status of nuclear power in India and the potential impact of India- Japan nuclear cooperation,” Citizens’ Nuclear Information Center, Tokyo, November 6, 2015
- “Nuclear Energy in China and India: Can Ambitions Meet Reality?” Kyoto University, Kyoto, November 4, 2015
- “Assessing Risk Assessment: Nuclear Regulation and Reactor Safety,” Princeton Institute for International and Regional Studies, Princeton University, Princeton, October 15, 2015
- “Nuclear Fission Energy: Status and Policies,” ExxonMobil – Princeton University Workshop, Princeton, October 13, 2015
- “Nuclear India: Politics, Rhetoric and Reality,” The Alliance for a Secular and Democratic South Asia & Science for the People, Massachusetts Institute of Technology, Cambridge, October 5, 2015
- “Challenges in Licensing Small Modular Reactors,” Bapeten (Nuclear Energy Regulatory Agency of Indonesia), Jakarta, June 26, 2015

- “Reprocessing and Breeder Reactors in India,” International Panel on Fissile Materials Panel on the Global Challenge of Reprocessing and Plutonium Disposal, NPT Review Conference, United Nations, New York, May 7, 2015
- “Nuclear Energy: Global Overview & the Case of India,” Program on International Relations and Strategic Affairs, Princeton University & Center for Policy Research, Princeton, April 9, 2015
- “Atomic Development and Democratic Dissent: Opposition to the Koodankulam Nuclear Plant in India,” Lecture, Program for South Asian Studies, Princeton University, Princeton, March 4, 2015
- “Nuclear Energy After Fukushima,” Colloquium, Department of Physics, Ohio State University, February 23, 2015
- “Nuclear Energy in India: Current Status and Future Outlook,” Korea Advanced Institute of Science and Technology, Daejeon, December 22, 2014
- “Nuclear Energy in India: Historical Record and Future Prospects,” Institute of South Asian Studies, National University of Singapore, August 19, 2014
- “Nuclear Power in India: History and Prospects,” Melbourne University, August 15, 2014
- “Motivations and Challenges for Small Modular Reactors,” Nuclear Engineering Department, Universidade Federal do Rio de Janeiro, March 18, 2014
- “The Power of Promise: Examining the Feasibility of a Rapid Expansion of Nuclear Energy in India,” South Asia Institute and the Kennedy School Project on Managing the Atom, Harvard University, Cambridge, December 6, 2013
- “Fukushima: Implications for the Understanding of Severe Accidents and the Future of Nuclear Energy,” Colloquium, Department of Physics, Case Western University, Cleveland, November 21, 2013
- “Nuclear Energy: Issues in India and Around the World,” Presentation at Prayas Energy Group, Pune, November 1, 2013
- “Challenges in Licensing Small Modular Reactors,” Trilateral Meeting, University of Maryland, College Park, September 19-20, 2013
- “Nuclear Energy and Climate Change,” Presentation at the Heinrich Böll Foundation, Beijing, August 6, 2013
- “Nuclear Power: Why, What, Why Not,” Lecture, Vermont Law School, South Royalton, July 12, 2013
- “Nuclear Arms Race in South Asia: The Case of India,” Lecture at the Heinrich Böll Foundation, Berlin, April 29, 2013
- “The Future of Nuclear Energy in India: History, Technology, and Economics,” Program in South Asia Studies, Princeton University, Princeton, March 28, 2013
- “Nuclear Energy in India: History, Technology, and the Future,” King’s College London, March 20, 2013
- “The Potential for Severe Accidents Associated with Nuclear Power,” Round Table on Liability Legislation in India, New Delhi, March 17, 2013 (over Skype)
- “Nuclear Energy in India: Learning from the Past, Thinking about the Future,” Indian Institute of Technology, Madras, February 22, 2013
- “The Power of Promise,” Jawaharlal Nehru University, New Delhi, February 20, 2013

- “Risk Perception in the Indian Nuclear Establishment,” The Energy and Resources Institute (TERI), New Delhi, February 20, 2013
- “Nuclear Power: Motivations and Problems,” National Institute of Immunology, New Delhi, February 19, 2013
- “Nuclear Energy in India: Perspectives on its Past, Present and Future,” Madras Institute of Development Studies, Madras, February 18, 2013
- Is Nuclear Energy the Answer to India's energy needs? Loyola College, Madras, February 18, 2013
- “Nuclear Accidents and Learning: The Indian Experience,” National Institute of Advanced Studies, Bangalore, February 15, 2013
- “Nuclear Energy in India: Past and Future,” Indian Institute of Management, Bangalore, February 14, 2013
- “Nuclear Energy in India: Perspectives on its Past, Present and Future,” Hyderabad Central University, Hyderabad, February 13, 2013
- “Nuclear Energy in India,” Panel Discussion at Lamakaan: An Open Cultural Space, Hyderabad, February 12, 2013
- “Worried in Koodankulam: Nuclear Safety and Public Protests in India,” Lecture at the San Jose Peace and Justice Center, San Jose, December 22, 2012
- “Organizing for Nuclear Disarmament and Peace in India,” Hiroshima/Nagasaki Commemoration, Coalition for Peace Action, Princeton, August 6, 2012
- “Small Modular Reactors: Features, Motivations,” Exploring the End of Nuclear Power and Examining its Proliferation and Health Problems, Institute for Energy and Environmental Research, Washington, D.C., July 25, 2012
- “Connections Between Nuclear Power and Nuclear Weapons: Production,” Exploring the End of Nuclear Power and Examining its Proliferation and Health Problems, Institute for Energy and Environmental Research, Washington, D.C., July 25, 2012
- “Nuclear Power: Why, What, Why Not,” Lecture, Vermont Law School, South Royalton, July 13, 2012
- “Small Modular Reactors: Overview,” Seminar at the Brookhaven National Laboratory, Upton, New York, May 9, 2012
- “Nuclear Power After Fukushima,” Colloquium, Department of Mathematical Sciences, Montclair State University, Montclair, New Jersey, November 30, 2011
- “The Future of Nuclear Power” Fall 2011 Maclean House Lecture Series, Sponsored by the Office of the Alumni Association, Princeton University, Princeton, October 6, 13, & 20, 2011
- “The Economics of Nuclear Power,” Seminar at the Indian Institute of Science, Bangalore, August 29, 2011
- “Nuclear Power: Risk and Ethics,” Lecture at Ashoka Trust in Ecology and Environment, Bangalore, August 29, 2011
- “United Kingdom,” Presentation at panel discussion on “The Challenges of Spent Fuel Management: Experience and Lessons from Around the World” at the AAAS Center for Science, Technology and Security Policy, Washington D.C., June 3, 2011

- “Nuclear Power: Global Trends, Future Projections,” Presentation at panel discussion on “The Jobs, Costs, and Security Landscape of a US Nuclear Expansion,” Organized by Center for Earth, Energy, and Democracy, Institute for Agriculture and Trade Policy, Minneapolis, March 25, 2011
- “Implications of Fukushima for Nuclear Safety: A Preliminary Assessment,” Presentation at panel discussion on “After the Earthquake: Japan’s Nuclear Plant Crisis” at the Woodrow Wilson School for Public and International Affairs, Princeton University, March 24, 2011
- “Nuclear Energy and Climate Change,” Plenary Lecture at the Conference on “Towards a Nuclear Weapon Free World” and the 10th Anniversary National Convention of the Coalition for Nuclear Disarmament and Peace, New Delhi, December 11, 2010
- “Nuclear Power: Current Trends, Future Projections, Developing Countries,” Bulletin of the Atomic Scientists, Doomsday Clock Symposium, Washington, D. C., November 4, 2010
- “Looking up at the Apocalypse: Disarmament, Climate Change, and Justice,” Panel Presentation at “For a Nuclear Free, Peaceful, Just, Sustainable World Conference”, Riverside Church, New York City, May 1, 2010
- “India: Climate Debates, Energy Trends,” Princeton Environmental Institute, Princeton University, February 5, 2010
- “Dealing with Climate Change: Equity, Justice, and Social Change,” Climate Change Panel, Bulletin of the Atomic Scientists, Doomsday Clock Symposium, New York City, January 13, 2010
- “A Nuclear Powered Solution to Climate Change: Feasible? Desirable?,” Environment Affairs Forum, Princeton University, November 24, 2009
- “India’s Energy Future: How Much Can Nuclear Power Contribute?,” Science, Technology, and Environmental Policy Seminar, Princeton University, September 28, 2009
- “Nuclear Energy in India: History and Future,” Rotary Club, Bangalore, March 14, 2009
- “Kya Dam Hai? The Economics of Nuclear Power,” Gujarat Vidyapeeth, December 8, 2008
- “Between Three Hard Places: India's Energy and Climate Change Policies,” Seminar, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, October 14, 2008
- “Nuclear Power as a Solution to Climate Change?,” Seminar, John F. Welch Technology Centre, General Electric Company, Bangalore, September 15, 2008
- “Economic Costs of Nuclear Power in India,” Seminar, Indian Institute of Management, Bangalore, March 21, 2008
- “Can Nuclear Power Help with Climate Change? Lessons from the Experience in India and Elsewhere,” Lecture for Postgraduate Certificate Course on Technology and Sustainable Development, Indian Institute of Technology, Madras, January 14, 2008
- “The Nuclear Deal and the Evolving Indo-US Relationship,” Lecture for course on “Globalization”, Swaraj Vidyapeeth, Bangalore, December 29, 2007
- “Indo-US Nuclear Deal,” Talk to CONCERNS, Student Group, Indian Institute of Science, Bangalore, November 17, 2007
- “The US-India Nuclear ‘Deal’: Underlying Issues and Debates,” Seminar, Institute for Social and Economic Change, Bangalore, November 15, 2007

- “Some Aspects of the US India Nuclear Deal,” Seminar, Indian Statistical Institute, Bangalore, November 7, 2007
- “Nuclear Energy: Economic and Environmental Aspects,” Lecture for course on “Approaching the Environment in India – New Theories and Methods in the Study of the Nature-Society Interface,” Institute for Social and Economic Change, Bangalore, August 9, 2007
- “Implications of the US India Nuclear Deal,” Presentation to the Citizens for Alternatives to Nuclear Energy, Bangalore, April 19, 2007
- “Breeder Reactors: Overview and Economics,” Seminar, National Institute for Advanced Studies, Bangalore, November 29, 2006
- “An Overview of Nuclear Power in India,” Presentation to the Greenpeace International Advisory Committee, Greenpeace, Bangalore, June 4, 2006
- “India: Prisoner of the Nuclear Dream,” Special Energy and Environmental Policy Lecture, Center for Energy and Environmental Policy, University of Delaware, May 18, 2006
- “The US-India Nuclear Deal,” Seminar, Science, Technology and Global Security Working Group, Program in Science, Technology and Society, Massachusetts Institute of Technology, May 12, 2006
- “Nuclear Power in India: Failed Past, Dubious Future,” Seminar, Nonproliferation Policy Education Center, Washington, D.C., May 10, 2006
- “The US-India Nuclear Deal,” Seminar, Center for International Security and Cooperation, Stanford University, May 1, 2006
- “The US-India Nuclear Deal,” Joint Seminar with Zia Mian, South Asia Studies Committee, Princeton University, April 25, 2006
- “Nuclear Weapons in India: Glimpses from History” and “Atomic Energy in India”, Two lectures at the National Law School of India University, Bangalore, April 1, 2006
- “South Asia: Under the Nuclear Shadow,” Seminar, Liu Institute for Global Studies, University of British Columbia, Vancouver, Canada, November 23, 2005
- “Promises and Failures: The Story of Atomic Energy in India,” Colloquium, Raman Research Institute, Bangalore, October 6, 2005
- “Nuclear Power: Plans, Prospects, and Constraints,” Presentation to Greenpeace, Bangalore, August 24, 2005
- “Nuclear Power in India: Current Status, Future Prospects,” Seminar, Centre for International Security and Cooperation, Stanford University, July 20, 2005
- “Ionizing Radiation and Health,” Lecture, Bangalore Planetarium, May 27, 2005
- “Technology Choices and their Implications: the Case of Nuclear Energy in India,” Lecture, Course on Technology and Policy in India, Indian Institute of Management, Bangalore, March 16, 2005
- “Economics of Nuclear Power in India,” Seminar, Institute for Social and Economic Change, Bangalore, February 17, 2005
- “Nuclear Energy and Nuclear Weapons: Issues for an Informed Public Debate,” Public Lecture, Organized by Society for Promoting Participative Ecosystem, Prayas, Centre for Environment Education, and others, Pune, January 12, 2005

- “Technology and Development: Nuclear Energy in India,” Two lectures, Course on Technology and Sustainable Development, Indian Institute of Technology, Chennai, January 4, 2005
- “Future of Nuclear Power in India,” Lunch Seminar, Program on Science and Global Security, Princeton University, October 1, 2004
- “Nuclear Power in India: An Overview,” Seminar, Department of Chemical Engineering, Indian Institute of Science, Bangalore, August 19, 2004
- “Secrecy and India’s Nuclear Establishment,” Lecture, Alternate Law Forum, Bangalore, May 21, 2004
- “A Progressive Bomb?,” Seminar, China Study Group, New York, January 31, 2004
- “An Estimate of India’s Uranium Enrichment Capacity,” Lunch Seminar, Program on Science and Global Security, Princeton University, August 6, 2003
- “Nuclear Power in India,” Seminar, Center for Energy and Environmental Policy, University of Delaware, May 15, 2003
- “Steps Towards Operationalizing the Indian Nuclear Arsenal,” Lunch Seminar, Program on Science and Global Security, Princeton University, January 22, 2003
- “Normal Accidents and Nuclear War,” Lecture, Course on “Engineers in Society,” New Jersey Institute of Technology, October 24, 2002
- “Deployment of Nuclear Weapons and Early Warning in South Asia,” Technical Seminar, Security Studies Program, Massachusetts Institute of Technology, October 10, 2002
- “Beyond Missile Defense,” Division of Natural Sciences and Mathematics Colloquium, Colgate University, April 19, 2002
- “Health Impacts from Uranium Mining in India,” Presentation to ASHA, Princeton University, February 16, 2002
- “The Environmental and Health Impacts of the Nuclear Fuel Cycle,” Seminar, Institute for Social and Economic Change, Bangalore, January 3, 2002
- “Uranium Mining and Health in India,” Presentation to ASHA, Columbia University, November 4, 2001
- “Economics of Nuclear Power from Fast Breeder Reactors in India,” Seminar, Indira Gandhi Institute for Development Research, August 20, 2001
- “Nuclear Power Economics in India: Fast Breeders vs. Heavy Water Reactors,” Seminar, Center for Energy and Environmental Studies, Princeton University, July 10, 2001
- “Scientists and India’s Nuclear Bomb,” Seminar, Center for International Security and Cooperation, Stanford University, March 13, 2001
- “Scientists and India’s Nuclear Bomb,” Lecture, Yale Center for International and Area Studies, Yale University, October 26, 2000
- “Nuclear Weapons in South Asia: A Scientist’s Perspective,” Presentation to the Stanford India Association, Stanford University, June 29, 2000
- “Prisoners of the Nuclear Dream: India, Pakistan, and the Making of Nuclear Nations,” Seminar, Program on Science, Technology and Society, Massachusetts Institute of Technology, February 19, 1999

- “Nuclear Energy and Weapons in South Asia,” Seminar, Gettysburg College, January 29, 1998
- “The Effects of Nuclear Explosions - a Case Study of Mumbai,” Seminar, School of International Studies, Jawaharlal Nehru University, New Delhi, February 24, 1997
- “Walking Technicolor Signatures at Hadron Colliders,” Seminar, Center for Theoretical Studies, Indian Institute of Science, Bangalore, July 1992
- “Electroweak Symmetry Breaking, Walking Technicolor, and the SSC,” Seminar, Department of Physics, University of Wuppertal, Germany, February 1992